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# THE MONT CENIS TUNNEL.

(*Continued from page* 121.)

## THE GEOLOGY OF THE TUNNEL.

Before considering the mineralogical and geological formation of that portion of the Alps separating Bardonnèche from Modane, it may be interesting to devote a short space to a review of the geological characteristics of the Alps in general.

The word "Alpen" is of great antiquity, and it is believed that it has been transferred from the language of the most ancient inhabitants of Italy. It is asserted that it is derived from the Sabines, the two monosyllables "Alp" and "Pen" of which it is composed, meaning repectively "white" and "head," the combination having reference to the perpetual snows covering the higher summits of the chain. It is not known why this name, which might well be applied to any snow-covered mountains, should only have been given to those surrounding Northern Italy.

The Mont Schiavo forms the beginning of the Italian Alps, on the Mediterranean side, and they terminate with Mont Bittoray at the Adriatic, not far from the city of Fiume. The ridge extends in a curve about 955 miles in length taken along the peaks of the chain. This great circle of mountains surrounding Northern Italy, bears very different aspects on its inner and its outer faces. If we start from the highest peaks of the Alps, and descend on the outer side, we find a long continuation of ascents and descents, with comparatively easy slopes, whereas on the inner faces the plains are reached by a series of very abrupt spurs. Thus, for instance, Mont Blanc, the highest peak of the Alps, offers an easy ascent from Savoy, while on the Italian side it rises almost perpendicularly to a vast height above the valley of Aosta. So also, while the river Po, at Saluzzio, falls 5,249 ft. in a distance of 21 miles, the Rhine, in descending from the same height, runs as far as Lake Constance, a distance of 92 miles.

It may be assumed that the whole Alpine chain is bounded by a line, drawn at the foot of the mountains through Mondovi, Sallizzo, Pinerolo, Ivrea, Biella, Como, Bergamo, Brescia, Peschiera, Udine, Trieste, and Pola, and beyond Italy by another line, which beginning at Mondovi crosses Mont Schiavo to Abenga, as far as Nice, and thence passes by Entrevaux, Seyne, Geneva, Villeneuve, Altorf, Innsbrük, and Laïbach; thence, crossing the top of the Bittoray, it reaches Pola, and completes the enclosing line.

The Italian Alps form a series of clusters or heads, the principal of which are 7 in number, and these have been named from the mountain that has the greatest number of spurs, and not from the one most conspicuous in height.

They are:

1. The group of the Stura and of the 4 Bishoprics.

2. The group of Bardonecchia or of the Tabor.

3. The group of the Isera or of Mont Iseran.

4. The group of Mont Blanc.

5. The group of Mont Saint Gothard.

6. The group of Malaggio.

7. The group of the Pizzo dei tre Signori.

The group of Bardonecchia is situated north of the sources of the torrent Dora Riparia, and it extends from Mont Cenis to Mont Ginevro, giving birth to the two principal branches of the Dora, one of which springs from Mont Ginevro, while the other descends from the top of the Great Miol, and is at first known as the Ripa, and afterwards the Dora Riparia.

The idea of opening the tunnel through the Alps with the object of facilitating the communication between England and France, is due to M. Médail, a native of Bardonnèche. This gentleman, whose pursuits led him frequently across the mountains that surrounded his native village, ascertained the way in which, from the valley of the Arc, at whose head is Modane, at the foot of the western side of Mont Frejus, it was possible to descend to the banks of the Rhone, by continually skirting the torrent of the Arc without any rapid gradients, by keeping always on the sides of the high spurs to the right and left. The same facilities seemed to be offered by nature for the construction of a railway from Bardonnèche to Susa. The only obstacle in uniting France and Italy was therefore the construction of a tunnel under Mont Frejus, so as to join Bardonnèche and Modane. This point of crossing was the only one that could be selected, involving a tunnel of no greater length than the one that has been constructed. In 1841 M. Médail published a pamphlet at Lyons upon this subject. The work, however, obtained no attention, and the author died without the satisfaction of seeing even the first steps taken in the matter which he had advocated.

When the construction of the Mont Cenis tunnel was first discussed as a practicable and probable scheme, the popular notions as to the geological difficulties that would be encountered were as numerous as they were original, and were equalled by the prejudices that arose on all sides, springing even from high scientific sources. To investigate the validity of the opposition coming from responsible persons, the Sardinian Government requested Professor Angelo Sisimunda to report fully upon the prospects of the work. We shall here only briefly allude to the results of his labors, which were presented in due course to the Secretary of State for Public Works.

Professor Sisimunda found the distribution of rocks between Bardonnèche and Modane to be as follows: Arenaceous, micaceous, and schistous united together—quartzites—chalk (internally anhydrite) with limestone and sometimes with dolomites, and lastly crystalline schistous lime, alternating with argillaceous and decomposed schists.

Professor Sisimunda divided these rocks into 3 groups, and named them as follows:

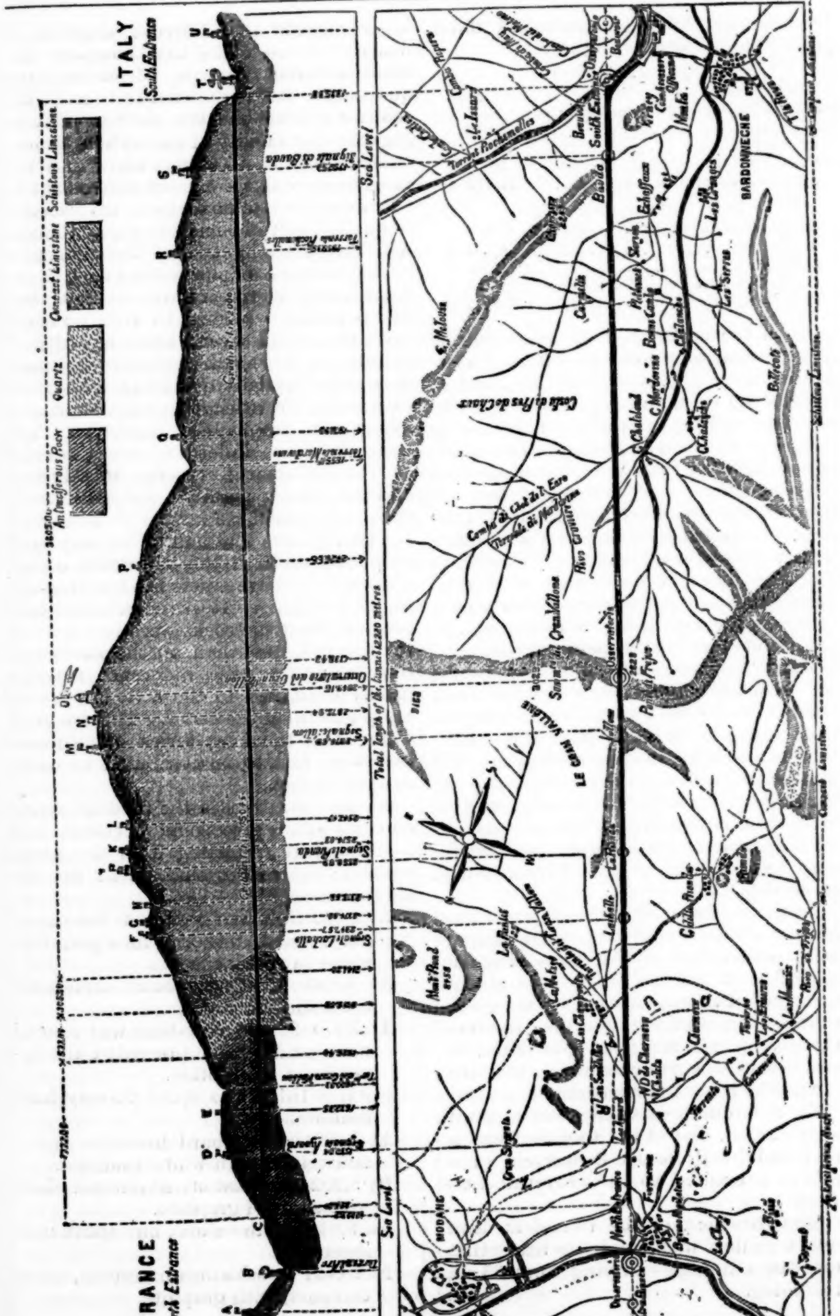
1. Superior group. Anthracite, which includes the micaceous arevania, with schists and quartzites.

2. Group represented by oolite, and including the lime and chalk. This group is, according to the report, a continuation of the great stratum of the same nature near Villette, in Tarantasia.

3. Inferior group. Anthracite and schistous lime, with metamorphic and argillaceous schists.

It is easy to prove a discordance in the stratification between the schistous lime of the inferior anthraciferous system and silicious lime, the chalk and dolomite representing the superior lias formation, and the inferior oolite. This fact is almost universal in the Alpine chain, and is caused by a constant undulation in the rocks. The irregularity of stratification between the silicious lime and the layer of quartzite that is above it, and which is almost vertical, might be the effect of the ruption which has taken place, and which runs across the Alps in a direction from south to north. The displacement of the rocks having taken place in the direction of the depth of the formation, the succession of the strata would not, according to Professor Sisimunda, have undergone any change from the ruption.

The plan and section of Mont Frejus on the following page show the position of the different strata to which we have referred. In order to give an idea of the dimensions of the strata, it may be remarked that their widths vary on the outer surface and within the mountain;


ITALY
South Entrance
FRANCE
North Entrance
Anthraciferous Rock
Quartz
Contact Limestone
Schistous Limestone
Sea Level
Total length of the tunnel 12220 metres
Signale di Bardo
Signale Lachelle
LE GRAN VALLONE
BARDONNECHE
MODANE

the following table of inner and outer profiles gives the exact figures :

| | Ft. | In. |
|---|---|---|
| *On the Surface.* | | |
| Anthraciferous rocks—widths of stratum | 5,814 | 3 |
| Quartzites | 1,761 | 9 |
| Compact limestone and dolomites. | 1,004 | 0 |
| Schistous limestone | 31,512 | 4 |
| *Inside and along the Tunnel.* | | |
| Anthraciferous rocks— width of stratum | 6,879 | 3 |
| Quartzites | 1,274 | 6 |
| Compact limestone and dolomites | 1,166 | 8 |
| Schistous limestone | 3,0774 | 2 |

Upon the surface on the Bardonnèche side the schistous limestone has an average dip varying between 20 deg. and 25 deg. to the west, and from 40 deg. to 45 deg. on the west, increasing at the Col de Frejus to as much as 50 deg. The chalk is so distorted that the stratification is not recognizable. The quartzites are nearly vertical at the commencement of the stratum; they incline towards the south-west at an angle varying from 90 deg. to 65 deg. The anthraciferous sandstone inclines in some parts towards the north-west, at others to the south-east, and at the extreme point it is nearly vertical.

Inside the mountain along the tunnel the schistous limestone inclines from north-west to east at an angle varying from 5 deg. to 10 deg. The chalk stratum is also here indistinguishable. The quartzites incline to the north-east at varying angles between 50 deg. and 60 deg., then it becomes vertical. The anthraciferous sandstone dips from north-west to east, with angles of from 50 deg. to 80 deg.

In the course of the tunnel excavation on the Modane side, frequent changes were observed in the degrees of the inclination of the rocks, but the general direction of this inclination always tended towards the west; it was also observed that before reaching the quartzites, the strata made a curve resembling the letter C with the convex parts turned eastwards.

In the tunnel quartzite was met with about 295 ft. east of the spot that was anticipated by Professor Sisimunda in his report presented to the Government in 1845.

The direction of the tunnel is nearly north 14 deg. west, and the axis strikes the strata at angles varying from 34 deg. to 40 deg.

As regards the different degrees of density of the rocks that compose the three different groups, of course the quartzites were the hardest and the schistous limestone the softest. But as regards the facility of excavation by mechanical means, all miners know that homogeneous rocks are more convenient to excavate than others which are variable in quality, soft in some places, and mixed with quartzites in others. The quartzites on the Modane side presented such an extraordinary degree of hardness that steel and percussion seemed to have no effect upon them, and several hundreds of steel chisels (as we shall hereafter see) have been worn out dailyto make a few insignificant holes, notwithstanding the enormous mechanical appliances employed. The quartzites were indeed at times as hard as regular quartz crystals, translucent, and sometimes slightly colored like amethyst. We shall see further on how great the efforts were that had to be employed to pierce through the wall which nature appeared to have erected to bar the daring undertaking. It was ascertained with certainty that the rocks were less hard on the line of tunnel than on the surface of the mountain ; the difference may be chiefly attributed to the action of the atmosphere upon the latter. The frequent changes in the long series of schistous limestone has to be attributed to metamorphic action.

As this stratum is the predominating one, we shall give some particulars as to its nature. Starting from the south opening, the aspect changes in the following manner:

At 1,640 ft. it was granulous limestone, gary, hard, uniform in color, with splits in regular layers.

At 4,880 ft. it was black limestone, hard and laminating.

At 5,570 ft. the limestone was colored with oxides, and presented the appearance of eufotide.

From 6,161 ft. to 6,286 ft. very hard limestone.

At 7,020 ft. very hard limestone, gray, and veined with white granules.

At 8,202 ft. schistous limestone, black, with signs of graphite.

At 9,840 ft. the same, but splitting in layers.

At 13,097 ft. schistous limestone, not so compact, with graphite.

At 13,123 ft. very hard black limestone, granulous, like granite.
At 14,960 ft. very black limestone, with hornblende, but not very hard.
At 15,380 ft. black limestone, mixed with graphite and albite.
At 19,000 ft. white limestone, a little crystallized.
At 19,284 ft. black limestone, not hard, combined with layers of very hard white limestone.

These particulars, together with the plan and section upon page 227, will, we hope, give clear and detailed information upon the geological character of the Alps along the axis of the tunnel.

## THE EARTH A MAGNET.

From Proctor's "Light Science for Leisure Hours."

There is a very prevalent but erroneous opinion, that the magnetic needle points to the north. We remember well how we discovered in our boyhood that the needle does not point to the north, for the discovery was impressed upon us in a very unpleasant manner.

We had purchased a pocket compass and were very anxious—not, indeed, to test the instrument, since we placed implicit reliance upon its indications—but to make use of it as a guide across unknown regions.

Not many miles from where we lived lay Cobham Wood, no very extensive forest certainly, but large enough to lose one's self in. Thither accordingly we proceeded with three school-fellows. When we had lost ourselves we gleefully called the compass into action, and made from the wood in a direction which we supposed would lead us home. We travelled on with full confidence in our pocket guide; at each turning we consulted it in an artistic manner, carefully poising it and waiting till its vibrations ceased. But when we had travelled some two or three miles without seeing any house or road that we recognized, matters assumed a less cheerful aspect. We were unwilling to compromise our dignity as explorers by asking the way, a proceeding which no precedent in the history of our favorite travellers allowed us to think of. But evening came on and with it a summer thunder shower. We were getting thoroughly tired out and the *hæc olim meminisse juvabit* with which we had comforted ourselves began to lose its force. When at length we yielded, we learned that we had gone many miles out of our road, and we did not reach home till several hours after dark. How it fared with our school-fellows we know not, but a result overtook ourselves personally for which there is no precedent, so far as we are aware, in the records of exploring expeditions. Also the offending compass was confiscated by justly indignant parents, so that for a long while the cause of our troubles was a mystery to us. We now know that instead of pointing due north, the compass pointed more than 20 deg. toward the west, or nearly to the quarter called by sailors north-northwest. No wonder, therefore, that we went astray when we followed a guide so untrustworthy.

The peculiarity that the magnet needle does not in general point to the north, is the first of a series of peculiarities which we now propose briefly to describe. The irregularity is called by the sailors the needle's *variation*, but the term more commonly used by scientific men is the *declination* of the needle. It was probably discovered a long time ago, for 800 years before our era the Chinese applied the magnet's directive force to guide them in journeying over the great Asiatic plains; and they must soon have detected so marked a peculiarity. Instead of a ship's compass, they made use of a magnetic car, on the front of which a floating needle carried a small figure whose outstretched arm pointed southwards. We have no record, however, of their discovery of the declination, and know only that they were acquainted with it in the 12th century. The declination was discovered, independently, by European observers, in the 13th century.

As we travel from place to place, the declination of the needle is found to vary. Christopher Columbus was the first to detect this. He discovered it on the 13th of September, 1492, during his first voyage, and when he was 600 miles from Ferro, the most westerly of the Canary

Islands. He found that the declination, which was towards the east in Europe, passed to the west, and increased continually as he travelled westwards.

But here we see the first trace of a yet more singular peculiarity. We have said that at present the declination is towards the west in Europe. In Columbus's time it was towards the east. Thus we learn that the declination varies with the progress of time as well as with change of place.

The genius of modern science is a weighing and a measuring one. Men are not satisfied nowadays with knowing that a pecularity exists; they seek to determine its extent, how far it is variable, whether from time to time, or from place to place, and so on. Now the results of such inquiries applied to the magnetic declination have proved exceedingly interesting. We find first that the world may be divided into two unequal portions, over one of which the needle has a westerly, and over the other an easterly declination Along the boundary line, of course, the needle points due north.

England is situated in the region of westerly magnets. This region includes all Europe except the northeastern parts of Russia, Turkey, Arabia, and the whole of Africa, the greater part of the Indian Ocean and the western parts of Australia, nearly the whole of the Atlantic Ocean, Greenland, the eastern parts of Canada, and a small slice from the northeastern part of Brazil.

All these form one region of westerly declination; but, singularly enough, there lies in the very heart of the remaining and larger region of easterly magnets an oval space of a contrary character. This space includes the Japanese Islands, Manchouria, and the eastern parts of China. It is very noteworthy also that in the westerly region the declination is much greater than in the easterly. Over the whole of Asia, for instance, the needle points almost due north. On the contrary, in the north of Greenland, and of Baffin's Bay, the magnetic needle points due west; while still further to the north (a little westerly) we find the needle pointing with its north end directly towards the south.

In the presence of these peculiarities it would be pleasant to speculate.

We might imagine the existence of powerfully magnetic *veins* in the earth's solid mass, coercing the magnetic needle from a full obedience to the true polar summons. Or the comparative effects of oceans and of continents might be called into play. But, unfortunately for all this, we have to reconcile views founded on *fixed* relations presented by the earth with the process of *change* indicated above. Let us consider the declination of England alone.

In the 15th century there was an easterly declination. This gradully diminished, so that in about the year 1657 the needle pointed due north. After this the needle pointed towards the west, and continually more and more, so that scientific men, having had experience only of a continual shifting of the needle in one direction, began to form the opinion that this change would continue, so that the needle would pass through north-west and west to the south. In fact, it was imagined that the motion of the needle would resemble that of the hands of a watch, only in a reversed direction.

But before long, observant men detected a gradual diminution in the needle's westerly motion. Arago, the distinguished French astronomer and physicist, was the first (we believe) to point out that "the progressive movement of the magnetic needle towards the west appeared to have become continually slower of late years" (he wrote in 1814); "which seemed to indicate that after some little time longer it might become retrograde." Three years later, namely on the 10th of February, 1817, Arago asserted definitely that the retrograde movement of the magnetic needle had commenced to be perceptible. Colonel Beaufoy at first oppugned Arago's conclusion, for he found from observations made in London during the years 1817–1819, that the westerly motion still continued. But he had omitted to take notice of one very simple fact, viz. that London and Paris are two different places. A few years later the retrograde motion became perceptible at London also, and it has now been established by the observations of 40 years. It appears from a careful comparison of Beaufoy's observations that the needle reached the limit of its western digression (at Greenwich) in March, 1819, at which time the declination was nearly 25 deg. In Paris, on the contrary, the needle had reached its greatest western digression

(about 22½ deg.) in 1814. It is rather singular that, although at Paris the retrograde motion thus presented itself 5 years earlier than in London, the needle pointed due north at Paris 6 years later than in London, viz. in 1663. Perhaps the greater amplitude of the needle's London digression may explain this peculiarity.

"It was already sufficiently difficult," says Arago, "to imagine what could be the kind of change in the constitution of the globe which could act during 153 years in gradually transferring the direction of the magnetic needle from due north to 23 deg. west of north. We see that it is now necessary to explain moreover how it has happened that this gradual change has ceased, and has given place to a return towards the preceding state of the globe."

"How is it," he persistently asks, "that the directive action of the globe, which clearly must result from the action of molecules of which the globe is composed, can be thus variable while the number, position, and temperature of these molecules, and, as far as we know, all their other physical properties, remain constant?"

But we have considered only a single region of the earth's surface. Arago's opinion will seem more just when we examine the change which has taken place in what we may term the magnetic aspect of the whole globe.

The line which separates the region of westerly magnets from the region of easterly magnets now runs, as we have said, across Canada and eastern Brazil in one hemisphere, and across Russia, Asiatic Turkey, Indian Ocean, and West Australia in the other; besides having an outlying oval to the east of the Asiatic continent. Now these lines have swept round a part of the globe's circuit in a most singular manner since 1600. They have varied alike in direction and complexity. The Siberian oval, now distinct, was in 1787 merely a loop of the eastern line, of no declination. The oval appears now to be continually diminishing, and will one day probably disappear.

We find here presented to us a phenomenon as mysterious, as astonishing, and as worthy of careful study as any embraced in the wide domains of science. But other peculiarities await our notice.

If a magnetic needle of suitable length be carefully poised on a fine point, or, better, be suspended from a silk thread without torsion, it will be found to exhibit each day two small, but clearly perceptible, oscillations. M. Arago, from a careful series of observations, deduced the following results :

At about 11 at night the north end of the needle begins to move from west to east, and having reached its greatest easterly excursion at about 8¼ in the morning, returns toward the west to attain its greatest westerly excursion at 1¼. It then moves again to the east, and having reached its greatest easterly excursion at 8½, returns to the west, and attains its greatest westerly excursion at 11, as at starting. Of course these excursions take place on either side of the mean position of the needle, and as the excursions are small, never exceeding the fifth part of a degree, while the mean position of the needle lies some 20 deg. to the west of north, it is clear that the excursions are only nominally eastern and western, the needle pointing throughout far to the west.

Now, if we remember that the north end of the needle is that farthest from the sun, it will be easy to trace in M. Arago's results a sort of an effort to turn towards the sun—not merely when that luminary is above the horizon, but during his nocturnal path also. We are prepared, therefore, to expect that a variation, having an annual period, shall appear on a close observation of our suspended needle. Such a variation has long since been recognized. It is found that in the summer of both hemispheres the daily variation is exaggerated, while in the winter it is diminished. But besides the divergence of a magnetized needle from the north pole, there is a divergence from the horizontal position, which must now claim our attention. If a non-magnetic needle be carefully suspended so as to rest horizontally, and be then magnetized, it will be found no longer to preserve that position. The northern end dips very sensibly. This happens in our hemisphere. In the southern it is the southern end that dips. It is clear, therefore, that if we travel from one hemisphere to the other we must find the northern dip of the needle gradually diminishing, till at some point near the equator the needle is horizontal ; and as

we pass thence to southern regions, a gradually increasing southern inclination is presented. This has been found to be the case, and the position of the line along which there is no inclination (called the *magnetic equator*) has been traced around the globe. It is not coincident with the earth's equator, but crosses that circle at an angle of 12 deg., passing from north to south of the equator in longitude 30 deg. west of Greenwich, and from south to north in longitude 187 deg. east of Greenwich. The form of the line is not exactly that of a great circle, but presents here and there (and especially where it crosses the Atlantic) perceptible excursions from such a figure. At 2 points on the earth's globe the needle will rest in a vertical position. These are the magnetic poles of the earth.

The northern magnetic pole was reached by Sir J. G. Ross, and lies in 70 deg. north latitude and 263 deg. east longitude, that is, to the north of the American continent, and not very far from Boothia Gulf. One of the objects with which Ross set out on his celebrated expedition to the Antarctic seas was the discovery, if possible, of the southern magnetic pole. In this he was not successful. Twice he was in hopes of attaining his object, but each time he was stopped by a barrier of land. He approached so near, however, to the pole, that the needle was inclined at an angle of nearly 90 deg. to the horizon, and he was able to assign to the southern pole a position in 75 deg. south latitude and 154 deg. east longitude. It is not probable, we should imagine, that either pole is fixed, since we shall now see that the inclination, like the declination of the magnetic needle, is variable from time to time as well as from place to place; and in particular the magnetic equator is apparently subjected to a slow but uniform process of change.

Arago tells us that the inclination of the needle at Paris has been observed to diminish, year by year, since 1671. At that time the inclination was no less than 75 deg.; in other words, the needle was inclined only 15 deg. to the vertical. In 1791 the inclination was less than 71 deg. In 1831 it was less than 68 deg. In like manner, the inclination at London has been observed to diminish from 72 deg. in 1786 to 70 deg. in 1804, and thence to 68 deg. at the present time.

It might be anticipated from such changes as these that the magnetic equator would be found to be changing in position. Nay, we can even guess in which way it must be changing. For since the inclination is diminishing at London and Paris, the magnetic equator must be approaching these places, and this (in the present position of the curve) can only happen by a gradual shifting of the magnetic equator from east to west along the true equator. This motion has been found to be really taking place. It is supposed that the movement is accompanied by a change of form; but more observations are necessary to establish this interesting point.

Can it be doubted that while these changes are taking place the magnetic poles also are slowly shifting round the true pole? Must not the northern pole, for instance, be further from Paris, now that the needle is inclined more than 23 deg. from the vertical, than in 1671, when the inclination was only 15 deg. It appears obvious that this must be so, and we deduce the interesting conclusion that each of the magnetic poles is rotating around the earth's axis.

But there is another peculiarity of the needle which is as noteworthy as any of those we have spoken about. We refer to the intensity of the magnetic action—the energy with which the needle seeks its position of rest. This is not only variable from place to place, but from time to time, and is further subject to sudden changes of a very singular character.

It might be expected that where the dip is greater the directive energy of the magnet would be proportionately great. And this is found to be approximately the case. Accordingly the magnetic equator is very nearly coincident with the equator of least intensity, but not exactly. As we approach the magnetic poles we find a more considerable divergence, so that instead of there being a northern pole of greatest intensity nearly coincident with the northern magnetic pole, which we have seen lies to the north of the American continent, there are two northern poles one in Siberia, nearly at the point where the river Lena crosses the Arctic circle; the other not so far to the north, only a few deg. north in fact of Lake Superior. In the south, in a like manner, there are also 2 poles, one on the Antarctic circle,

about 130 deg. east long. in Adelie Island, the other not yet precisely determined, but supposed to lie or about to lie on about the 24th deg. of long., and south of the Antarctic circle. Singularly enough, there is a line of lower intensity running right around the earth along the valleys of the two great oceans, passing through Behring's Straits, and bisecting the Pacific, on one side of the globe, and passing out of the Arctic Sea by Spitzbergen, and down the Atlantic on the other.

Colonel Sabine discovered that the intensity of the magnetic action varies during the course of the year. It is greatest in December and January in both hemispheres. If the intensity had been greatest in winter, one would have been disposed to have assigned seasonal variation of temperature as the cause of the change. But as the epoch is the same for both hemispheres, we must seek another cause.

Is there any astronomical element which seems to correspond with the law discovered by Sabine? There is one very important element: the position of the perihelion of the earth's orbit is such that the earth is nearest to the sun on about the 31st of December or the 1st of January. There seems nothing rashly speculative, then, in concluding that the sun exercises a magnetic influence on the earth, varying according to the distance of the earth from the sun. Nay, Sabine's results seem to point very distinctly to the law of variation. For, although the number of observations is not as yet very great, and the extreme delicacy of the variation renders the determination of its amount very difficult, enough has been done to show that in all probability the sun's influence varies according to the same law as gravity, that is, inversely as the square of the distance.

That the sun, the source of light and heat, and the great gravitating centre of the solar system, should exercise a magnetic influence upon the earth, and that this influence should vary according to the same law as gravity, or as the distribution of light and heat, will not appear perhaps very surprising. But the discovery by Sabine that *the moon* exercises a distinctly traceable effect upon the magnetic needle seems to us a very remarkable one. We receive very little light from the moon, much less (in comparison with the sun's light) than most persons would suppose, and we get absolutely no perceptible heat from her. Therefore, it would seem rather to the influence of mass and proximity that the magnetic disturbances caused by the moon must be ascribed. But if the moon exercises an influence in this way, why should not the planets? We shall see that there is evidence of some such influence being exerted by these bodies. More mysterious, if possible, than any of the facts we have discussed, is the phenomenon of *magnetic storms*. The needle has been exhibiting for several weeks the most perfect uniformity of oscillation. Day after day the careful microscopic observation of the needle's progress has revealed a steady swaying to and fro, such as may be seen in the masts of a stately ship at anchor on the scarce-heaving breast of ocean. Suddenly a change is noted; irregular jerking movements are perceptible, totally distinct from the regular periodic oscillations. A magnetic storm is in progress. But where is the centre of disturbance, and what are the limits of the storm? The answer is remarkable: If the jerking movements observed in places spread over very large regions of the earth—and in some well-authenticated cases over the whole earth—be compared with the local time, it is found that (allowances being made for difference of longitude) *they occur precisely at the same instant*. The magnetic vibrations thrill in one moment through the whole frame of our earth. But a very singular circumstance is observed to characterize these magnetic storms. They are nearly always observed to be accompanied by the exhibition of the aurora in high latitudes, northern and southern. Probably they never happen without such a display; but numbers of auroras escape our notice. The converse proposition, however, *has* been established as an universal one. No great display of the aurora ever occurs without a strongly-marked magnetic storm.

Magnetic storms last sometimes for several hours or even days.

Remembering the influence which the sun has been found to exercise upon the magnetic needle, the question will naturally arise, has the sun anything to do with magnetic storms? We have clear evidence that he has. On the 1st of September, 1859, Messrs. Carrington and

Hodgson were observing the sun, one at Oxford, and the other in London. Their scrutiny was directed to certain large spots which, at that time, marked the sun's face. Suddenly, a bright light was seen by each observer to break out on the sun's surface, and to travel, slowly in appearance, but in reality at the rate of about 7,000 miles in a minute, across a part of the solar disc. Now it was found afterwards that the self-registering magnetic instruments at Kew had made at that very instant a strongly marked jerk. It was learned that at that moment a magnetic storm prevailed at the West Indies, in South America, and in Australia. The signal-men in the telegraph stations at Washington and Philadelphia received strong electric shocks; the pen of Bain's telegraph was followed by a flame of fire; and in Norway the telegraphic machinery was set on fire. At night great auroras were seen in both hemispheres. It is impossible not to connect these startling magnetic indications with the remarkable appearance observed upon the sun's disc.

But there is other evidence. Magnetic storms prevail more commonly in some years than in others. In those years in which they occur most frequently it is found that the ordinary oscillations of the magnetic needle are more extensive than usual. Now, when these peculiarities had been noticed for many years, it was found that there was an alternate and systematic increase and diminution in the intensity of magnetic action, and that the period of the variation was about 11 years. But, at the same time, a diligent observer had been recording the appearance of the sun's face from day to day, and from year to year.

He had found that the solar spots are in some years more freely displayed than in others, and he had determined the period in which the spots are successively presented with maximum frequency to be about 11 years. On a comparison of the two sets of observations, it was found (and has now been placed beyond a doubt by many years of continued observations) that magnetic perturbations are most energetic when the sun is most spotted, and *vice versa*.

For so remarkable a phenomenon as this, none but a cosmetical cause can suffice. We can neither say that the spots cause the magnetic storms, nor that the magnetic storms cause the spots. We must seek for a cause producing at once both sets of phenomena. There is as yet no certainty in this matter, but it seems as if philosophers would soon be able to trace in the disturbing action of the planets upon the solar atmosphere the cause as well of the marked period of 11 years, as of other less distinctly marked periods, which a diligent observation of solar phenomena is beginning to educe.

## PROGRESS OF THE IRON AND STEEL INDUSTRIES IN FOREIGN COUNTRIES.

By DAVID FORBES, F.R.S., &c.

From "The Journal of the Iron and Steel Institute."

II.

In accordance with the views enunciated in the first of these reports, their contents will be in future arranged under two heads, viz.:—

A. Metallurgical topography, embracing all information possessing a strictly local interest in connection with the iron and steel manufactures in the different countries alluded to in these reports; and

B. Metallurgical technology, which will contain descriptions and results of new processes, improvements, machinery, physical or chemical investigations, etc., directly or indirectly connected with the metallurgy of iron and steel in foreign countries.

### A. *Metallurgical Topography.*

AUSTRIA.—A recent work, edited by F. M. Friese, one of the Government mining officials, gives full statistical data as to the production of iron in this country. It embraces the years from 1826 to 1868, in which latter year the total make of pig iron amounted to 6,698,547 centners, or 329,718 English tons. Details from official sources are given of the production of the ironworks, taken separately, and their

position shown upon a map, which accompanies this book, "Uebersicht der Roheisen Produktion der Oesterreichischen Monarchie, von F. M. Friese, K. K. Berghauptman, mit 9 Tabellen, u. 1 Karte, Vien 1870, Waldheim."

A sketch of the industrial history of the Horovitzer Ironworks in Bohemia, by Strippelmann, has appeared in the February and March numbers of the "Berg u. Huetten. Zeit." It may be mentioned that the ironworks of this district are probably some of the oldest on record, for, although the historian Hajek dates the commencement of Bohemian iron metallurgy in the year 777, and Karsten puts it as late as the 9th century, it appears that mention is made of these works by Pubitschka in A. D. 596. In the "Zeitsch. d. Berg. u. Huetten. Vereins f. Kärnthen," a paper is given by W. Hupfeld on the results as yet obtained from smelting iron ores with coke in Carinthia; whilst in the same number is a description of the Reichenberge spathic iron mines near Assling; and in the "Berggeist," 1870, No. 15, a notice of the great iron deposits at Eisenerz, in Steiermark.

At the rolling mills of the Southern Railway in Gratz, the old rails, crop ends, and scrap are heated in a gas furnace, and then added to a bath of good gray pig iron, melted with some spiegeleisen in a Siemens-Martin furnace. When the sample shows that the desired quality of steel is attained, the metal is tapped into large pouring pots lined with clay, from which the ingots are filled. The bottom of the furnace is made of quartz sand, so arranged as to be kept cool by a current of air, whilst the sides and roof are of Dinas bricks. ("Zeitsch. d. Deutsch, Oesterr. Eisen. Stahl. u. Maschin. Industrie." 1870.)

Knut Styffe's report on the iron metallurgy of 1867, as represented by the Paris Exhibition, has been translated from the Swedish into German by Herr Tunner.

Since the publication of the last quarterly report, we have received Professor Kerperley's report on the advances made in iron smelting in the year 1868, only very recently published, "Bericht ueber die Fortschritte der Eisenhütten Technik, im Jahre, 1868, Leipzig, Felix," and need hardly add that it fully maintains the reputation of its predecessors, and it is much to be regretted that we have no similar work in England.

Belgium.—The iron trade of this country has, during the last three months, remained in much the same depressed condition as during the previous quarter, the bright hopes of its recovery, which the termination of the Franco-German war gave rise to, having for the time at least been overclouded by the effects of the civil war now raging in France.

With regard to the home trade, orders, especially for plates, foundry pig, slit rods, and merchant iron, have been tolerably abundant, and the demand much greater than could have been expected under the circumstances; but this has not been the case with the export trade, which has been extremely depressed—especially so for rails; and, as is well known, the iron industry of Belgium must always be mainly dependent upon its exportation. Under the impression that the return of peace would cause a sudden and important reaction in favor of the Belgian iron trade, several of the proprietors and companies, in order to meet the expected demand, and probably also with the desire of keeping their men together and in employment during this period of depression, have occupied themselves in enlarging or otherwise increasing the capabilities of their works; thus, Messrs. Dordolot Frères have been authorized by royal decree to add a fourth blast furnace, along with three steam boilers, to their Bouffioulx Works; the Société Anonyme de Grivegnée was authorized to add to their works, ten puddling furnaces, one 15-horse power steam hammer, one roughing mill, ten cylindrical boilers to work at 60 lbs. pressure, and to be heated from the waste flames from the puddling furnaces, along with two more steam engines of respectively 20 and 2 horse power, the former to work the weighing trains, and the latter as a feed engine. The extension of the Clabecq Works, and those of the Juville Rolling Mills Co., are likewise authorized.

The civil war in France, following immediately upon the announcement of peace with Germany, has now still further postponed the good time supposed to be coming for the iron works, and created a feeling of despondency in many of those connected with the Belgian iron trade.

The official tables giving the statistics of the Belgian iron trade for the year 1870, have now appeared, and show that, whilst there has been an increase of no less than 59,480 tons in the importation of iron ore, pig, scrap, and other iron goods, there has, in the same period, been a decline in the exports of similar articles to the extent of 27,222 tons.

The following figures are condensed from the official tables, and will give at a glance the actual state of the trade, as far as exportation and importation are concerned :

| | Imported 1870. | Imported 1869. | Increase. |
|---|---|---|---|
| | Tons. | Tons. | Tons. |
| Iron ore | 567,523 | 551,990 | 15,633 |
| Pig and scrap iron | 83,799 | 61,599 | 22,200 |
| Iron gooods (exclusive of minerals) | 92,722 | 71,041 | 21,681 |

| | Exported 1870. | Exported 1869. | Increase. | Decrease. |
|---|---|---|---|---|
| | Tons. | Tons. | Tons. | Tons. |
| Iron ores | 178,562 | 164,576 | 13,986 | .... |
| Pig and scrap iron | 8,232 | 14,266 | .... | 6,034 |
| Rails | 122,926 | 136,186 | .... | 13,260 |
| Plates | 20,705 | 21,058 | .... | 353 |
| Other rolled iron | 75,648 | 81,631 | .... | 5,983 |

The exports of iron wire remained, in 1870, stationary, as compared to 1869. The names of the countries to which, in the years 1870 and 1869, the entire exports of Belgian iron of every description (iron ores excepted) were forwarded, and the respective quantities, are as under:—

| DESTINATION. | 1870. | 1869. | Increase. | Decrease. |
|---|---|---|---|---|
| | Tons. | Tons. | Tons. | Tons. |
| Russia | 62,755 | 73,681 | .... | 10,926 |
| Swden and Norway | 1,889 | 733 | 1,156 | .... |
| Denmark | 317 | 649 | .... | 332 |
| Zollverein | 57,994 | 41,685 | 16,309 | .... |
| Hanse Towns | 3,654 | 4,936 | .... | 1,282 |
| Netherlands | 28,902 | 27,760 | 1,142 | .... |
| England | 13,318 | 11,716 | 1,602 | .... |
| France | 30,349 | 40,094 | .... | 9,745 |
| Spain | 3,301 | 480 | 2,821 | .... |
| Italy | 7,723 | 19,807 | .... | 12,084 |
| Switzerland | 2,809 | 4,109 | .... | 1,300 |
| Austria | 1,383 | 1,391 | .... | 8 |
| Roman States | 35 | 28 | 7 | .... |
| Turkey | 17,810 | 29,790 | .... | 11,980 |
| Egypt | 1,506 | 1,389 | 117 | .... |
| United States | 11,924 | 11,669 | 255 | .... |
| Cuba and Porto Rico | 2,141 | 1,101 | 1,040 | .... |
| English Possessions | 168 | 56 | 112 | .... |
| Brazil | 594 | 659 | .... | 65 |
| Rio de la Plata | 232 | 616 | .... | 384 |
| Chili and Peru | 588 | 466 | 122 | .... |
| Miscellaneous | 462 | 326 | 136 | .... |
| Total | 249,874 | 273,141 | .... | 23,267 |

The attention of the Belgian ironmasters is becoming more and more directed towards the production of steel, and amongst others, the Société de Sclessin have erected works for making steel by the Siemens-Martin process.

CANADA.—It would appear from the report of Professor Bell, of the Geological

Survey of Canada, that the iron industry of this country, more especially as regards the exploration and exportation of iron ore, is somewhat reviving and progressing. The well-known Hull iron mines, which had been closed for more than a year, and which produce a fine quality of magnetic ore, have come into the hands of a new company, called the Forsyth Mining Co., by whom they were re-opened in August, last year, and about 3,500 tons of ore of 67 per cent. iron had been extracted before the end of the year. The St. Francis River Ironworks, which smelt bog iron ore, and produce a very tough white iron, much used for the manufacture of the cast railway carriage wheels so commonly employed in North America, have continued in vigorous operation. This class of iron ore is also worked extensively at Mr. Larne's new works, near Three Rivers, and at the St. Maurice works. A new company, with a capital of $500,000, has also been formed, to take over the works of the original Moisie Iron Company. In Belmont, the Cobourg, Peterboro', and Marmora Railway and Mining Company have spent considerable sums in improving railway communication with their mines, at which they employ above 100 men, and shipped ore (magnetic oxide) to the amount of 10,000 tons last year. In 1869, however, the produce was 20,000 tons. Several other mines about this place cannot be worked at present for want of better means of communication. The Chaffey mine and the Matthew's mine, both near Newboro', have sent respectively 3,150 and 4,750 tons of magnetic iron by barges to Kingston, and thence by ship to Cleveland, Ohio; whilst from the Cowan mine, about 12 miles west of Perth, a deposit of rich hematite is being worked, containing an average of 60 per cent. iron, of which about 5,000 tons have been already extracted. The very extensive deposits of iron ore which occur in Canada, to the east shore of Lake Superior, still remain unworked; but now that Canadian iron ores are coming into demand for supplying the United States, it seems probable that these ores also will soon attract attention.

FRANCE.—Owing to the war, and the consequent disorganization of everything in this unhappy country, no trustworthy information respecting the actual state of the iron and steel manufacture in France has come to hand, and no official returns of production, etc., have been obtained of later date than those for the first half-year of 1870, given in the last quarterly report.

From the official report published last year, the following figures are taken as showing the production in 1869:

| | Metrical Tons. | English Tons. |
|---|---|---|
| Pig iron, smelted with charcoal | 70,400 | |
| Do. do. do. and coke | 34,100 | |
| Do. do. coke | 573,650 | |
| Valued at about £5,120,000.—Total, 1869 | 678,150 | equal to 637,494 |
| Do. do. do. 1868 | 606,695 | Do. 566,841 |
| Increase in 1869 | 71,455 | |
| Wrought iron, produced with charcoal | 18,300 | |
| Do. do. do. do. and coke | 11,400 | |
| Do. do. do. coke | 444,650 | |
| Valued about £3,440,000.—Total 1869 | 474,350 | equal to 466,904 |
| Do. 1868 | 401,780 | Do. 395,471 |
| Increase in 1869 | 72,570 | |

The value of the steel production (quantity not given) in 1869, is as follows:

| | Francs. | |
|---|---|---|
| Puddled, hearth, and Bessemer steel | 35,976,524 | |
| Cementation (blister) steel | 2,166,140 | |
| Cast steel | 12,418,510 | |
| Sheet steel | 780,600 | |
| Total | 51,341,774 | or, about £ 2,053,600 |

An interesting scientific description of the great deposits of iron, which occur in the metamorphic crystalline rocks in the island of Elba, so celebrated for their beautifully crystallized native oxides of iron, and from having been worked from the oldest periods in the metallurgical history of this metal, has lately been pub-

lished by Vom Rath, in the "Zeitsch. d. deutsch. Geolog. Gesellsch." xxii., p. 591.

GERMANY.—According to the official report, which is published in detail in the "Zeitsch. f. d. Berg Hutten un Salinen Wesen. i. d' Preussische Staate," vol. xviii., 1870, the production of iron ore in Prussia was, in 1869, as follows:

| | Number of Mines. | Workmen. | Production. Zoll. Centner. | Production. English Tons. |
|---|---|---|---|---|
| Private establishments | 1,142 | 23,921 | 55,210,239 | 2,714,172 |
| Government do. | 25 | 1,269 | 2,701,150 | 132,938 |
| Total | 1,167 | 25,190 | 57,911,389 | 2,847,110 |

If arranged geographically, these results are as follows :

| MINING DISTRICTS. | Mines. | Workmen. | Zoll. Centner. |
|---|---|---|---|
| Breslau (Silesia) | 95 | 4,564 | 11,394,823 |
| Halle (Prussian Saxony) | 11 | 87 | 146,287 |
| Dortmund (Westphalia, Hanover, Rhine) | 48 | 2,765 | 12,096,996 |
| Bonn (Westphalia, Rhine, Hohenzollern, Hesse-Nassau, Waldeck) | 957 | 17,039 | 31,012,858 |
| Clausthal (Hanover, Hesse-Nassau) | 56 | 735 | 3,260,425 |
| | 1,167 | 25,190 | 57,911,389 |

And if arranged according to the mineralogical nature of the ores :

| | 1869, Zoll. Centner. | 1868, Zoll. Centner. | Increase. | Decrease. |
|---|---|---|---|---|
| Bog iron ore | 798,744 | 1,180,789 | .... | 382,045 |
| Brown hematite | 24,733,659 | 21,490,538 | 3,243,121 | .... |
| Spathic carbonate | 11,149,117 | 10,657,837 | 491,280 | .... |
| Clay ironstone | 1,212,212 | 1,661,773 | .... | 449,561 |
| Blackband (Kohleneisenstein) | 6,358,884 | 6,533,840 | .... | 174,996 |
| Hematite (with a little limonite) | 10,450,092 | 10,154,735 | 295,357 | .... |
| Magnetic iron ore | 201,709 | 193,913 | 7,796 | .... |
| Limonite (Bohnerz) | 3,007,012 | 2,372,253 | 634,759 | .... |
| Total | 57,911,389 | 54,245,678 | 3,665,711 | .... |

The rapid increase in the production of iron ores, since 1855, may be seen from the following figures, which represent the average yearly extraction during the following periods :—

| | | |
|---|---|---|
| Average from | 1855 to 1857 | 20,247,640 Zoll. Centner. |
| Do. | 1858 to 1860 | 17,677,695 do. |
| Do. | 1861 to 1863 | 21,309,169 do. |
| Do. | 1864 to 1866 | 31,224,585 do. |
| Do. | 1867 to 1869 | 53,205,567 do. |

The exact figures for each of the last three years being as follows:—

| Year. | Mines Worked. | Men Employed. | Zoll. centner iron ore. | English tons. |
|---|---|---|---|---|
| 1867 | 1,405 | 23,094 | 47,699,639 | 2,347,379 |
| 1868 | 1,228 | 23,997 | 54,245,678 | 2,669,691 |
| 1869 | 1,167 | 25,150 | 57,911,398 | 2,849,107 |

With respect to the yield of the blast furnaces, the total quantity of cast iron made in 1869 in the Prussian States amounted to 23,611,587 zoll. centners, or 1,151,945 English tons, against 1,036,713 tons in 1868, or an increase of 11,523 tons over the preceding year. The particulars of production for 1869 are as follow :—

| District. | Furnaces. | | Smelted by | | Coke and Charcoal. | Total Production in Zoll. centners. |
|---|---|---|---|---|---|---|
| | In blast. | Idle. | Coke. | Charcoal. | | |
| Silesia | 74 | 43 | 4,169,409 | 511,171 | 147,265 | 4,827,845 |
| Brandenburg | 1 | 2 | ..... | 2,618 | ..... | 2,618 |
| Saxony (Prussian) | 2 | 2 | ..... | 73,767 | ..... | 73,767 |
| Westphalia | 53 | 16 | 5,593,744 | 290,410 | 598,773 | 6,482,927 |
| Hanover | 13 | 3 | 2,065,640 | 51,910 | 342 | 2,117,892 |
| Rhine Provinces | 19 | 32 | 8,506,628 | 100,881 | 633,914 | 9,241,423 |
| Hesse-Nassau | 26 | 4 | 341,571 | 497,644 | 13,756 | 852,971 |
| Hohenzollern | 1 | 1 | ..... | 9,189 | ..... | 9,198 |
| Waldeck | 1 | .. | ..... | 2,955 | ..... | 2,935 |
| Total 1869 | 270 | 103 | 20,676,992 | 1,540,545 | 1,394,050 | 23,611,587 |
| Do. 1868 | 264 | 100 | 18,577,068 | 1,600,255 | 887,876 | 21,065,199 |
| Difference. | 6 | 3 | 2,099,924 | 59,710 | 506,174 | 2,546,388 |

The total make of wrought iron of all descriptions in 1869 amounted to 15,250,059 Zoll. centners, or 747,542 English tons, against 605,831 tons in 1868; thus showing an increase of 141,701 tons.

The particulars of the products for 1869 are (given in Zoll. centners) as follow:—

| Provinces. | Bar iron of all sorts. | | Total. | Sheet. | Wire. | Total Wrought Iron, Zoll. centner. |
|---|---|---|---|---|---|---|
| | Coke made. | Charcoal made. | | | | |
| Silesia | 2,400,905 | 57,906 | 2,458,811 | 134,524 | 89,338 | 2,682,673 |
| Posen | .... | 3,750 | 3,750 | .... | .... | 3,750 |
| Prussia | 52,200 | 96,546 | 148,746 | .... | .... | 148,746 |
| Pomerania | .... | 22,464 | 22,464 | .... | .... | 22,464 |
| Brandenburg | 160,014 | 9,300 | 169,314 | 31,586 | .... | 200.900 |
| Saxony (Prussian) | 54,568 | 5,985 | 60,553 | 4,800 | 120 | 65,437 |
| Westphalia | 4,847,794 | 4,756 | 4,852,550 | 568,936 | 661,102 | 6,082,588 |
| Hanover | 49,935 | 7,735 | 57,670 | 14,000 | 356 | 72,026 |
| Rhine Provinces | 4,595,876 | 19,551 | 4,615,427 | 1,061,773 | 108,322 | 5,785,522 |
| Hesse-Nassau | 96,467 | 30,715 | 127,182 | 20,236 | 30 | 147,448 |
| Hohenzollern | .... | 11,100 | 11,100 | .... | .... | 11,100 |
| Schlesvig Holstein | .... | 24,000 | 24,000 | 462 | .... | 24.462 |
| Waldeck | 2,456 | 451 | 2,907 | .... | .... | 2,907 |
| Total in 1869 | 12,260,215 | 294,259 | 12,554,474 | 1,836,317 | 859,268 | 15,250,059 |
| Do. 1868 | 10,115.224 | 298,938 | 10,414,162 | 1,700,276 | 805,029 | 12,919,467 |
| Difference | 2,144,991 | 4,679 | 2,140,312 | 136,041 | 54,239 | 2,320,592 |

The estimated value of the entire production of cast and wrought iron in the Prussian States for the years 1869 and 1868 are given as under:—

| | 1869. | | 1868. | |
|---|---|---|---|---|
| | Prussian Thalers. | £ Sterling. | Prussian Thalers. | £ Sterling. |
| Cast iron of all descriptions | 43,353,602 | 6,283,130 | 37,688,951 | 5,462,166 |
| Wrought do. do. | 59,627,063 | 8,641,603 | 52,395,464 | 7,593,545 |
| | 92,980,665 | 14,924,733 | 80,083,415 | 13,055,711 |

The manufacture of steel is stated to have produced the following quantities in the years 1869 and 1868 respectively :—

| Year. | Ordinary Steel Zoll. Centners. | Cast and Bessemer Steel, Zoll. Centners. | Refined Steel. Zoll. Centners. | Total. | |
|---|---|---|---|---|---|
| | | | | Zoll. Centners. | English Tons. |
| 1869 | 792,252 | 2,055,444 | 139,623 | 2,987,319 | 147,018 |
| 1868 | 583,029 | 1,764,390 | 99,735 | 2,447,154 | 119,437 |
| Increase | 209,223 | 291,054 | 39,888 | 549,165 | 27,581 |

In Essen, although the effects of the war have been to increase the demand for certain descriptions of iron, especially those used for fortifications, still the prices have been kept down for the importation of iron from Belgium and Luxembourg, whilst the high prices of coke and want of hands have rendered the cost of the iron nearly as high as its selling price; so that many ironmasters have preferred blowing out their furnaces than making pig without profit. Some of the larger ironworks show an increase of make over 1870, but in the district of Siegen, where, in July last year, 35 furnaces were in blast, at present only 15 are in operation. The rolling mills have suffered more than the rail mills, and the future is considered to look gloomy. Certain brands are considered not likely to recover even after peace is established, and the effects of the war have been to establish the manufacture of spiegeleisen (hitherto almost confined to this district) in Sweden, and more recently in South Wales, at Ebbw Vale. A description is given by Dr. Klüpfel, in the "Berg. u. Huetten-Zeitung," 1871, p. 21, of the mode of occurrence of the iron ores pertaining to the Liassic formation of the Hartz, which have only been utilized during the last 10 years, in the course of which 4 large establishments for their reduction (the Porta, Tuetonia, Helmstädter, and Mathilde Smelting Works) have been erected. They contain 37½ per cent. iron in the wet state in which they come from the mine, or 44 per cent. when dry, along with 8 to 9 per cent. silica, a little more alumina, and from 1 to 2 per cent. carbonate of lime, and are found in very large quantities as regular beds, intercalated like the Cleveland ores between the other strata. In the same journal, a resumé of the different iron ores of the Clausthal district, in Hanover, gives their geological occurrence as follows:—In the Devonian limestones, beds and patches of brown hematite, and beds of both brown and red hematite; in the coal formation, veins of red hematite; in the magnesian limestone, mosses and patches of brown hematite, and spathic carbonate of iron; in the lias, beds of brown hematite and clay ironstone; in the chalk formation, beds of limonite (Bohnerz), which also occur along with beds of scoriaceous brown hematite, and patches and thin seams of silicious limonite in the middle Tertiary series, whilst bog iron ore is found in the alluvial deposits.

A volume containing a series of 10 working drawings of the ironworks at Kreuzthal, near Siegen, in Prussia, with details of the erections, blast furnaces, blowing machines, etc., has recently been published by Messrs. Hupfield & Schermeng, entitled "Hohofen-Anlage des Cöln-Musener Bergwerks-Aktien-Vereins in Kreuzthal, bei Siegen, Halle, Knapp I."

As regards South Germany, the official returns for 1869 show that in that year, 208 iron mines were in work, which employed 720 men, and produced 212,030 tons of iron ore, being an advance of 15½ per cent. upon 1868; the average production of iron ore in the 10 years from 1858 to 1868 amounted to 147,722 tons annually. Wrought iron made in 1869 was 127,226 tons, along with 400 tons steel. From Saxony we have as yet only returns for 1868, in which year 80 iron mines were worked by 445 men, and yielded 19,506 tons of ore, whilst the produce of the iron furnaces and steel manufacture only amounted to 19,812 tons of cast iron of all descriptions, 18,101 tons bar iron, 107 tons sheet, and 103 tons of steel.

POLAND.—This country being destitute of coal, all the iron produced is smelted with charcoal, and, as in all countries similarly situated, the make of the Polish ironworks, never very great, is declining, owing to the diminution and destruction of the forests, and the increasing price of fuel. So very little being known concerning the iron production of Poland, it may not be uninteresting to give the following statement, kindly furnished by M. W. Rau, of Warsaw, which shows the present annual make of charcoal pig iron in centners, and the names and number of blast furnaces, now in operation, at the private ironworks in that country:—

| Name. | Blast Furnaces. | Production. Centner. |
|---|---|---|
| Chlewisk | 2 | 50,000 |
| Przysucha | 1 | 20,000 |
| Drzewice | 1 | 30,000 |
| Krasny | 2 | 40,000 |
| Falków | 1 | 20,000 |
| Klinkiewiczow | 2 | 60,000 |
| Inowlodz | 1 | 20,000 |
| R. Bialoczew | 1 | 15,000 |
| Konskie | 2 | 50,000 |
| Rzucow | 1 | 15,000 |
| Noików | 1 | 15,000 |
| Boruchow | 1 | 20,000 |
| Korytkow | 1 | 20,000 |
| Machory | 1 | 20,000 |
| Chmielów | 1 | 15,000 |
| Borkowice | 2 | 40,000 |
| Szczesno | 1 | 15,000 |
| Blachownia | 2 | 40,000 |
| Kradzionów | 1 | 30,000 |
| Maleniec | 2 | 50,000 |
| Gustek | 1 | 20,000 |
| Poremba | 1 | 20,000 |
| Truskolas | 1 | 20,000 |
| Mijakow | 1 | 20,000 |

In all, 31 blast furnaces, which, from their small size, make only a total of 655,000 centners, or 32,728 English tons per annum, the make of each furnace varying from 750 to 1,500 tons yearly. Besides the above, there are some few furnaces which have lately come into the hands of a Russian company; and also, at Dabrowa, near the Prussian-Austrian frontier, the returns from which, although promised, have not as yet come to hand.

SWEDEN.—According to the Berggeist, the celebrated iron mines of Gellivara, in the North of Sweden, which were for some time worked by an English company, have now been stopped, principally on account of the great severity of the climate and the difficulties arising from want of communication and transport.

The construction of the Swedish Central Railway, now being made by an English company, which is proceeding rapidly (the first section from Frövi to Linda is to be opened in July, 1871), will bring the celebrated iron mines of Westmanland into direct railway connection with the port of Gottenburg, on the North Sea, and will, it is expected, thereby enable iron ores of 60 per cent., and great purity, to be exported and delivered on the east coast of England, at about 20s. per ton.

A memoir on the iron metallurgy of Sweden has been published in German by the eminent Austrian metallurgist, P. Tunner, entitled "Das Eisenhüttenwesen in Schweden. mit Holzsch u. 6 Tafeln. gr. 8 vo. Leipzig, Felix."

UNITED STATES.—Large deposits of aluminous brown hematite, containing 37 per cent. iron, with traces only of phosphoric acid, have been met with in Coshocton and Licking counties, Ohio. Considerable quantities of ore have been smelted with, it is stated, good results, in the charcoal furnaces along the Pittsburg and St. Louis line.

Professor Winshall has also communicated, at the meeting of the American Association, a description of immense beds of hydrated oxide of iron or bog ore, covering several townships, and said to be of unknown thickness and of great purity. These deposits are situated in the upper peninsula of Michigan, on the tributaries of the Monastique river, down which they can be floated to Lake Michigan. They lie in the direct track of the projected railroad intended to connect the North Pacific Railroad with the railway system of Michigan, and are regarded as of great value for mixing with the iron ores of the Lake Superior district; regarding which latter ores the furnace proprietors in Western Pennsylvania have held a meeting at Sharon, to make arrangements with the mines and railways for obtaining them at lower rates, as their present high prices tell greatly against them now that the duties on foreign iron have been lowered by the new tariff.

In the year 1869 no less than 65 new blast furnaces were built in the United States, and it is estimated that the iron production of the country gives direct employment to 140,000 workmen, besides some 800,000 more required for the further manufacture of the iron and steel

so produced. In the "Berg. u. Huetten Zeitung," for January, February, and March, 1871, a series of communications by Dr. Gustav Klüpfel, on the "Iron Metallurgy of the United States," will be found. They are illustrated, and contain many useful data concerning the actual condition of the iron manufacture in this country.

### B. *Metallurgical Technology.*

Smelting Iron Ores.—The trial of an entirely new style of furnace for reducing iron ores to cast iron is reported from Omaha, in the United States. It would appear from the very imperfect description as yet received, that the furnace employed is a sort of cupola, 25 ft. in height and 5 ft. in diameter, tapering towards the top. About half-way up the outside of the furnace is a steam pipe which encircles it, and from which 12 jets of steam blow off into the interior of the furnace, thereby producing a vacuum, and, consequently, drawing in a strong current of air from below, which does away with the necessity of having any blowing machine. This furnace is intended for smelting the iron ores of the large deposits, situated at Blackhills, near the highest level of the Union Pacific Railway, which that Company propose to utilize for the supply of iron for their foundry and workshops. This furnace is the invention of a Mr. Faucett, and, after a fortnight's trial, is reported to have worked so satisfactorily and economically that others are proposed to be built at once.

Chemistry of the Blast Furnace.—Mr. Lowthian Bell's work on the "Chemical Phenomena of Iron Smelting," has recently been translated into German, and published at Leipzig, by the eminent Austrian metallurgist, P. Tunner. The translation has been most favorably received and reviewed. Three papers on the "Chemistry of the Smelting of Cast Iron," by Herr C. Schinz, have appeared in Dingler's "Polytechnische Journal," for January and February, 1871; but as it is stated, in a foot note, that the substance of these communications has already appeared in England as an appendix to the English translation of Schinz's "Researches on the Action of the Blast Furnace," 1870, we must refer to that volume for their contents.

Blast.—A notice of Gjers's hot blast stove is given by P. Tunner, in the "Zeitsche. Berg. u. Huetten v. f. Kärnthen," 1871, p. 30, and some remarks by C. Schinz on Siemens' pyrometer, described in the first number of the "Journal of the Institute," are to be found in Dingler's "Polytechnische Journal," cxcviii., p. 394, in which he expresses an unfavorable opinion as to its accuracy, based on the belief that the electric relations will not continue the same in proportion to the increase in the temperature to be measured.

Root's (so-called) American blower, so far from being either a new or an American invention, is quite identical in principle with one long in use in England. Amongst others then employed in the Midland counties, one of these blowing machines was examined by the author (D. F) in 1846, at Messrs Elkington & Mason's Works in Birmingham.

Desulphuration of Coke.—An important paper on this subject, by M. Philippart, which has received the premium, and contains a summary of the different processes hitherto employed, is to be found in the "Revue Universelle des Mines," 1870, p. 315.

Puddling.—In the "Preussischer Zeitschr. f. Berg. Huetten u. Salinenwesen," 1870, p. 145, will be found an extremely interesting paper by Dr. Kosmann, in which he gives the results of a comparison between the effects and relative economy of puddling in the ordinary manner, and when done by Siemens' regenerative gas puddling furnace; although short, the space at command will only allow of our giving the conclusions arrived at, which are (1), that the Siemens furnace is to be preferred in all cases where an extremely high heat is required, and where the fuel is of bad quality and unsuited for producing sufficient heat when consumed in the ordinary way; (2) whenever a fixed temperature or a certain quality of flame is required for any length of time; (3) when no use of the waste heat of the flame (as for heating steam boilers to drive machinery) is required. And, in addition, there is less waste and also somewhat less loss of iron in the slag with the Siemens than with the ordinary furnace, as may be seen by a comparison of the chemical analysis of the respective slags.

| | Ordinary Furnace. | Siemens Furnace. |
|---|---|---|
| Silica | 11.98 | 15.36 |
| Alumina | 1.11 | 1.18 |
| Protoxide of iron | 68 69 | 66.33 |
| Do. manganese | 1.00 | 0 92 |
| Lime | 1.79 | 2.51 |
| Magnesia | 0.24 | 0 92 |
| Soda and potash | 2.13 | 0 72 |
| Phosphoric acid | 14.43 | 14 28 |
| Sulphur | 0 24 | 0.28 |
| Total | 101.61 | 102.50 |

The amount of phosphorus or sulphur eliminated in the slag is about the same in both instances. If, however, the fuel is of good quality, and the waste heat is employed for raising steam, then there appears to be little, if any, advantage in the employment of the Siemens furnace, which is known to be extremely costly, both in original construction and in subsequent repairs.

Purification of Iron and Steel.—In the last quarterly report, the Sherman process, then being tried at Pittsburg, in the United States, was briefly alluded to; but as the complete specification of the British patent, which the inventor had applied for, July 25th, 1870, No. 2,092, had not then been made public, the substance employed by him to effect the supposed purification was not at that time known.

It now appears that the claim made in this patent is for the use of iodine, or its compounds, to purify and eliminate phosphorus and sulphur from iron and steel. Quite independent, however, of the highly improbable supposition, that the addition of a small quantity of so extremely volatile a substance as iodine could effect such results as are claimed, it seems absolutely impossible that any such agent could be brought into actual contact with the whole of even the minute quantity of phosphorus or sulphur disseminated throughout all parts of so large a mass of iron, which, according to the rationale of this invention, it must necessarily do, in order to combine with the whole of these elements to carry them off. Lately, however, experiments on the large scale have been carried out in this country, and although the results are as yet not generally known, it is understood that they have decided conlusively against the claims of this process.

Another process for the attainment of the same objects, and very analogous in character to the above-mentioned, has still more recently been brought prominently forward in the United States, where it is called the Henderson process, also from the name of its inventor.

In an exposition of the main features of this method for refining iron, and for the production of steel and wrought iron, New York, December 15, 1870, the inventor, Mr. James Henderson, states that :—"The novelty of this invention consists in the employment of fluorine combined with oxygen. Fluorine is a more powerful agent than oxygen for the removal of silicon, and removes the silicon and the greater part of the phosphorus within 5 minutes of the beginning of the chemical reactions in the refining process. The sulphur and carbon are next acted upon and removed in the order in which they are named. The fluorine and oxygen are so combined as to insure simultaneous action upon the iron. The best results are obtained when oxygen, fluorine, and titanium or titanic acid are combined."

In this process, fluorspar, which is the fluoride of calcium (or other fluorides), is used as a source of fluorine, whilst the native oxides of iron (or other oxides), preferably those containing titanium are employed to supply the oxygen. In applying this system to the refining of the pig iron as it is tapped from the blast furnace, the mode of working is as follows : Cast-iron moulds or "chills" are prepared by having a mixture of 1 part fluorspar with 3 parts by weight of the iron ore, spread over their bottoms to a depth of from $\frac{1}{4}$ to $\frac{3}{8}$ of an in. (both of these substances having been intimately mixed with one another after having been powdered so finely as to have passed through a sieve of 400 meshes to the inch; the iron is then run into the chills so as to form slabs about 1 in. thick. What takes place may be described in Mr. Henderson's words :—" The heat of the iron causes fluorine and oxygen to be liberated, and by reason of the affinities of these substances for silicon and phosphorus, the impurities are removed in the form of vapor. The reactions in the chills are similar to those of the boiling puddling process, and last about 5 min.

The metal during this period is covered with jets of flame and smoke. The resulting metal, with respect to silicon and phosphorus, is as pure as wrought iron." The following analyses are given to show the composition of ordinary coke pig iron, made near Pittsburg, U. S., from a mixture of hematite with mill cinder, and of the refined cast iron and bar made from it by this patent process :—

| | Pittsburg coke, pig. | Refined cast iron. | Bar Iron. |
|---|---|---|---|
| Carbon, combined | 0.2040 | 0.3613 | Not determined. |
| Do. graphitic | 2.7685 | 2.5066 | Do. |
| Silicon | 2.3096 | ..... | .... |
| Slag | 0 3623 | 0 1983 | Not determined. |
| Phosphorus | 0.4196 | 0.1029 | 0.0087 |
| Sulphur | 0 1298 | 0.1269 | 0.0438 |

Whether these results will be confirmed by subsequent working on the large scale remains to be demonstrated, but at present Mr. Henderson sums up the advantages likely to ensue in the manufacture of bar iron from the use of his process as follows : (1.) Better quality, due to the purity of the refined pig, equal to wrought iron made from the best ores smelted with charcoal. (2.) The refined metal, being as free from sulphur and phosphorus as wrought iron itself, requires only decarbonizing, less skill to work it, and affords a more certain quality of product. (3.) Large saving in the cost of production, owing to the shortening of the time in puddling. (4.) Saving of nearly ½ the fuel per ton of iron. (5.) Reduction of general expenses to ½, owing to increased production. (6.) Reduction of 40 per cent. in wages per ton of iron by reason of diminished labor. (7.) The puddling furnace cinders contain but ¼ the ordinary quantity of phosphorus, and when smelted produce better iron.

A modification of this process, for the production of steel or wrought iron, is carried out in a reverberatory furnace, lined with the mixture of pulverized fluorspar and iron ore, preferably titaniferous, the cast iron as it is, or which has been previously refined in the chills as before described, being melted down and kept in the liquid state until, first, the whole of the phosphorus and sulphur, and subsequently the carbon, is removed; no stirring or labor is said to be required, the metal being tapped or balled according to the length of time, or as steel or wrought iron is required. An analysis of the steel made on the large scale at Pittsburg, U. S., by this process showing no trace of silicon or phosphorus, and only a trace of sulphur, is appended, but is of no value for comparison, since no analysis is given of the original pig iron from which they had been attained. Of this process, Mr. Henderson writes : "The refined iron is purer than is possible to be obtained in the pig mould-process, for the reason that the iron is kept fluid, and the reactions continue until all the slags or silicates, phosphorus and sulphur, are removed, so as to produce cast iron alloyed only with carbon; and the carbon may be progressively diminished to form high, medium, or low steel, or all be removed to form wrought iron in one operation, and these results are obtained without the labor of puddling or stirring the metal during the conversion ; the only labor required is 'balling' the steel or wrought iron, when the conversion is conducted in furnaces, wherein the temperature is not high enough to keep the metal liquid enough to be run from it."

Manufacture of Steel.—M. Aristide Berard has recently introduced into practical operation, at Givors, in France, a process for the direct conversion of pig iron into steel, for which, among other advantages, he claims that it effects a partial purification of the iron, by eliminating the sulphur, phosphorus, arsenic, etc. ; at least, to such an extent, that commoner brands of pig iron, which by no process at present known could be used, may be employed for making steel suitable for the manufacture of rails, tyres, etc. ; and that, by the combined action of air and gas, alternate oxidizing or reducing effects may be obtained at pleasure, so that the decarbonization

or recarbonization, and consequent uniform nature of the product, may be regulated, whilst, at the same time, the waste is reduced to a minimum. The main feature of the process is—the conversion of the fuel employed into a gaseous state, the use of a jet of superheated steam in so doing, and in the employment of a peculiarly-shaped converting furnace, in which from 3 to 5 tons of cast iron is treated at a time, the charge being run into the movable bed of the furnace, in the molten state, direct from the blast furnace or cupola. Spiegeleisen is added in the operation, and the waste is stated to be not more than from 7 to 8 per cent., whilst the operation is said to require only from 1 hour to 1½. The process has been fully described in a pamphlet, published by M. Berard; but as it would occupy too much of our space to give a detailed account of it, we may refer to a description, illustrated by figures, which has lately appeared in the "Engineer" of April 7th, 1871, where full particulars will be found.

Bessemer Steel.—In this manufacture, A. Brunner, in a communication, published in the "Oesterreich. Zeitsch. f. Berg. u. Huetten Wesen," February 20th, 1871, p. 59, advocates a combination of the Siemens-Martin process with the use of the Bessemer converter. The former process would only be used by him so far as to make a homogeneous quality of refined iron, which, after being brought to a high heat in the Siemens furnace, is tapped directly into the Bessemer converter, and blown as usual. By such means he considers that it would not be necessary to keep to certain brands of pig only for making such steel, but that all the less uniform quality of iron, at present unsuited for the manufacture of Bessemer steel, could be brought up to an uniform quality before being treated in the converter.

The slag produced in the Bessemer converter at Hörde has been examined by H. Scheerer, both chemically and crystallographically, the crystals being found in the centre of the bricks of slag which are produced by allowing the slag which remains behind in the converter, after the steel is poured, to run into a mould and consolidate. The analysis showed the slag to consist of :—

| | |
|---|---|
| Silica | 44 73 |
| Protoxide of iron | 20 59 |
| Do. manganese | 32 74 |
| Lime | 1.53 |
| Magnesia | 0.17 |
| | 99.76 |

As the ratio of the oxygen in the acid is to that of the bases as 23.85 to 12.43, or nearly double, the slag is evidently a bisilicate. The specific gravity was found to be 3.08, and the crystalline form triclinic, the angles closely approaching those of paisbergite, which is a native bisilicate of manganese, with a little lime and iron.

Classification of Bessemer Steel.—From a paper by E. F. Durre, of Berlin, in the "Preuss. Zeitsch. f. Berg. Huetten. u. Salinenwesen," on the Bessemer steel works of Seraing in Belgium, where this steel is made from Cumberland hematite pig, with an admixture of spiegeleisen, we extract the following observations. The steel from the converter is sorted into 3 classes, each of which is in turn subdivided according to hardness, as follows :

| | |
|---|---|
| I.<br>Absolute cohesion, 48 to 56 kilogrammes per square millimetre. Permanent extension, 20 to 25 per cent. Can be welded but not tempered..... | (*a*) Called "extra soft," contains less than from 0.25 to 0.35 per cent. carbon; is used for arms, artillery, boiler plate and sheet, rivets, etc. |
| II.<br>Absolute cohesion, 56 to 69 kilogrammes per square millimetre. Permanent extension, 10 to 20 per cent. Welds badly, and tempers badly..... | (*b*) Called "soft;" contains less than from 0.35 to 0.45 per cent. carbon; is used for machinery, tyres, axles, rails, etc.<br>(*c*) Called "half soft," or "half hard;" contains 0.45 to 0 55 per cent. carbon; is used for tyres, rails, pistons, and parts of machines exposed to friction. |
| III.<br>Absolute cohesion, 69 to 105 kilogrammes per square millimetre. Permanent extension, 5 to 10 per cent. Will not weld, but tempers well..... | (*d*) Called "hard;" contains from 0.55 to 0 65 per cent. carbon; is used for springs, cutting tools, files, saws, drills, and miners' tools, etc.<br>(*e*) Called "very hard;" contains about 0.65 per cent. carbon: is used for fine springs and tools, spindles for weaving, etc. |

In order to determine the class in this scale to which the steel belongs, three tests, respectively physical, mechanical, and chemical, are made use of.

1. *Physical.*—Only by the eye; the fracture and grain or texture of the steel being to the practised eye sufficient to enable it to be at once referred to one of these five classes; but, if not, a trial of its temper will at once settle the question.

2. *Mechanical.*—By bending under the hammer; class (*a*), at Seraing, admits of being bent U shape without breaking; or even, by repeated blows, allows both ends of the U to be closed together without fracture; whilst, on the other hand, the steel of class (*e*) breaks the moment the angle of bending reaches from 130 to 140 deg. Between these two extremes it is easy to arrange the others, on the basis that the hardness of a steel is proportionate to the angle at which it breaks when bent. These daily tests are occasionally checked by an actual determination of the actual cohesion and extension of the steel.

3. *Chemical.*—By determining the quantity of carbon in the steel. By a modification of the Eggertz coloration tests, this can be done in less than 2 hours, as follows: Two portions of the steel, in the shape of borings, each weighing 0.2 gramme, are dissolved in 20 cubic centimetres nitric acid of specific gravity 1.2, and heated to 80 deg. C. in a water bath. At the same time, two other similar trials are made each day with two steels containing different but known amounts of carbon (say, for example, 0.61 and 0.63 per cent. of carbon, always choosing samples with considerable carbon), so that these standard test solutions are always at hand for comparison. All the solutions are then placed in equally wide glasses, and brought to the shade of color of the standard test solution, by the addition of water, after which the volume of the solutions as compared with that of the standard test solutions, will enable the amount of carbon present to be calculated to within 0.03 percentage.

Strength of Steel.—In connection with steel it may not be devoid of interest to give a statement of the tests fixed for the strength of the cast steel work to be employed in construction of the great bridge over the Mississippi. The specification runs as follows:

"The steel shall be of the kind known in commerce as crucible cast steel. It will be required to stand the following tests, and failure to stand any one of such tests will be sufficient cause for the rejection of the piece. The staves comprising the tubes will be required to stand a compressive strain of 60,000 lbs., and a tensile strain of 40,000 lbs. per sq. in. of section without permanent set.

"They must stand a tensile strain of 100,000 lbs. per sq. in. without fracture. The modulus of elasticity shall not be less than 26,000,000, nor more than 30,000,000 lbs. This variation shall be avoided if possible, in which case the lower amount will be preferable. If a variation occurs in the modulus, bars having the same modulus must be selected in making up the tubes, so that one side of the tube shall not have greater power of resistance than the opposite one. Those having the same modulus shall be placed in the same tube. Each bar will be tested by the contractors, and the modulus stamped on it by the Illinois and St. Louis Bridge Company's inspector.

"The steel pins will be required to stand without permanent set a tensile strain of 40,000 lbs. per sq. in., and an ultimate tensile strain without fracture of 100,000 lbs. As it will be inconvenient to test these pieces, the engineer will require to have 2 or more of them made in one piece, and of sufficient length, cut from the middle or ends of the piece, a sample for testing. In such cases, failure of the sample will cause the rejection of the entire piece.

"Rods, bolts, eye-washers, rivets, etc., will be required to bear an ultimate tensile strain of 100,000 lbs. per sq. in. without fracture, and 40,000 lbs. per. sq. in. without permanent set. Such parts of the work will not be tested in tension beyond 40,000 lbs., sample pieces only being subjected to ultimate tests. Such tests as, in the judgment of the engineer or inspector, may be necessary to detect flaws or other imperfections, when the pieces cannot be conveniently subjected to trial in the testing machine, may be used, and any flaw or other imperfection existing in any piece will be sufficient cause for its rejection, if in the opinion of the engineer or inspector it is injured thereby.

"The $\frac{1}{4}$-in. plate steel for enveloping the

staves will be required to have a resistance to compression and tension without set equal to 40,000 lbs. per sq. in., and an ultimate tensile strength of 100,000 lbs."

CHEMICAL ANALYSIS.—Amongst the new works on chemical analysis specially devoted to the subject of the metallurgy of iron and steel, one has been recently published in French, entitled "Manuel pratique d'Analyse chimique appliquée à l'industrie du fer. Par MM. de Koninck et Dietz, 1 vol. 12mo. avec planche. Paris et Liége. Baudry 4 fr." Not having as yet received the book, we are not able to criticise its contents; its title, however, promises to supply a desideratum.

In Sweden, Prof. Eggertz, of Fahlun, so well known in connection with the chemical examination of everything connected with iron and steel, has recently published a work, "Om Kemisk profning af jern, etc., Fahlun, 1871," being instructions for the chemical analysis of iron ores, iron, steel, and fuel. This work cannot be too highly commended, but, unfortunately, until it is translated into English, it is to be feared that its being written in the Swedish language will make it inaccessible to most chemists or others interested in the subject.

The volumetrical determination of iron by means of hyposulphite of sodium, has lately been experimentally investigated by Oudemans, whose results, given in Frezenius's "Zeitsch, f. Analytische Chemie," 1871, p. 343, show that this process yields more accurate results when slightly modified by adding, in the first instance, a small excess of hyposulphite, and then, after determining the amount of this excess by titrating with a $\frac{1}{10}$ standard solution of iodine, deducting it, so as to get the true amount of hyposulphite used more correctly than by measuring it directly, as is usual.

The estimation of the total carbon in cast iron is recommended by Dr. Wittstein ("Polytech. Journal," Nov., 1870), to be conducted as follows:—About 1.25 gramme of the iron, in coarse powder, is placed in a flask already containing 50 gms. water, 10 gms. chloride of sodium, and 10 gms. sulphate of copper, and left for a couple of days in this solution; 10 gms. hydrochloric acid of Sp. Gr. 1.13 are then added, and the whole heated on a sand bath, by which the hydrated oxide of iron and finally divided metallic copper are dissolved, and after the liquid has been diluted with twice its bulk of water the carbonaceous matter remaining undissolved may be collected on a filter, which has previously been dried at 212 deg. Fahr., and weighed. After drying at 212 deg. Fahr. and weighing, the filter, with carbon, may be incinerated, when the amount of carbon will be found by subtracting the weight of the residue; traces of carbon sometimes remain with the ashes, as also a small quantity of copper and iron.

DETERMINATION OF SULPHUR IN CAST IRON.—Gintl ("Polytech. Journal exc.," p. 113) treats the iron with perchloride of iron, until it is as far as possible dissolved, after which the insoluble residue of carbon, sulphur, phosphorus, silicon, etc., is fused with a mixture of nitrate of potassium and caustic potash. All soluble matter is dissolved out of the fused mass with water, and to the filtered solution previously rendered acid by hydrochloric acid, chloride of barium is added, in order to precipitate the sulphuric acid as sulphate of barium, from the weight of which the sulphur present in the iron may be calculated.

In order to determine the amount of phosphorus in iron or steel, Belain "(Oesterreichische Zeitsch, f. Berg. u. Huetten," 1870, No. 33) recommends the iron to be dissolved in nitric acid, evaporated to dryness and the residue fused with carbonate of potassium or sodium; the fused mass must then be digested with water and filtered, when the phosphoric acid in the filtrate may be estimated by tituration with a standard solution of acetate of uranium, ferrocyanide of potassium being employed to indicate the end of the reaction, as this salt produces a brown cyanide of uranium when the reagent is in excess.

Kessler also describes in the "Journal, f. Prakt. Chemie," 1870, p. 364, a process he has devised for the determination of phosphorus in iron or steel, which consists in first removing the whole of the iron from its solution, by precipitation with ferrocyanide of potassium and subsequently precipitating the phosphoric acid remaining in the filtrate as phosphate of ammonia and magnesia as usual. As this paper, has, however, been translated in full in the "Chemical News," for February 17, 1871, this latter journal may

be referred to for particulars of the process.

In connection with the determination of phosphoric acid by the molybdate of ammonia process, Dr. Richter, in a paper in the "Polytechnische Journal," has shown that this precipitation is much interfered with by the presence of much sulphates or nitrates in the solution, so much so that if but very little phosphoric acid is present its precipitation may be altogether prevented; as a means of counteracting this source of error he finds that the addition of an excess of nitrate of ammonia to such solutions is sufficient to insure the precipitation of the yellow molybdo-phosphate of ammonia. Dr. Richter has also examined the yellow compound of silicic acid with molybdic acid, and finds that the presence of silica in solutions gives with the molybdate a yellow coloration like that produced from phosphoric acid, but that it only deposits after a very long time; this precipitate, although not immediately dissolved in ammonia as the phospho-molybdate is, does gradually dissolve, and when the magnesian salt is added it precipitates a silicate of magnesia which he thinks has often been confounded with the ordinary phosphate of magnesia and ammonia, and may thus have led to considerable errors in the determination of phosphorus in iron and its ores, etc.

Iron Deposited Galvanically.—The extreme difficulty of obtaining chemically pure iron, for the purpose of studying its properties, led to the attempts to precipitate it from its solutions by galvanic action, which is easily done by employing a weak battery and a solution of sulphate of iron, mixed with sulphate of magnesia; having, at the same time, sufficient carbonate of magnesia in the solution to keep it constantly neutral in proportion as the iron is reduced. Thus obtained, the iron presents itself as a fine-grained deposit, in which no trace of crystallization can be seen under the microscope. Its color is a soft light gray, and its hardness is so surprisingly great, that it can only be scratched with a file; it being at the same time so brittle, that a piece of $\frac{1}{8}$ of an inch thick can easily be broken between the fingers. These properties, however, at once change upon heating the iron; it then becomes very much softer, and as malleable as it was before brittle, and can be cut with the scissors with the greatest ease, as well as bent to and fro numerous times without breaking. Iron so deposited was, until lately, supposed to be pure iron, but the researches of the late Professor Graham on the occlusion of gases in metals caused Professor Jacobi to examine it more carefully "(Bulletin de l'Academie des Sciences de St. Petersburgh," xiv., p. 292), when he found that it in reality contained a considerable amount of hydrogen gas. Still more recently, this iron has been investigated by R. Lenz, "Annales des Physik. u. Chemie, Erganz." Bd. V., p. 242, whose results are of great interest, and are likely to throw some light on the subject of the absorption of gases by iron. He finds that all such electro-deposited iron contains very much hydrogen, with more or less carbonic acid, carbonic oxide, nitrogen, and water, and that it may have occluded in its substance as much even as 185 times its own bulk of these gases (principally hydrogen), which are evolved again on the application of heat. When heated out of contact with the air or oxidizing matters, this iron changes color, and becomes of a color exactly resembling platinum; and if now placed in water, a portion of the iron is oxidized at the expense of the oxygen in the water, whilst the hydrogen set free is at once absorbed, or again occluded by the rest of the iron.

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The metropolitan police report that the tramways already made facilitate traffic and cause no obstruction, except at a terminus, as at the foot of Westminster Bridge. But they have not yet been tried in the more crowded streets; that experiment has yet to be made. Under the circumstances the Board of Trade are unable to lay before Parliament a complete and perfect scheme for tramways in the metropolis.

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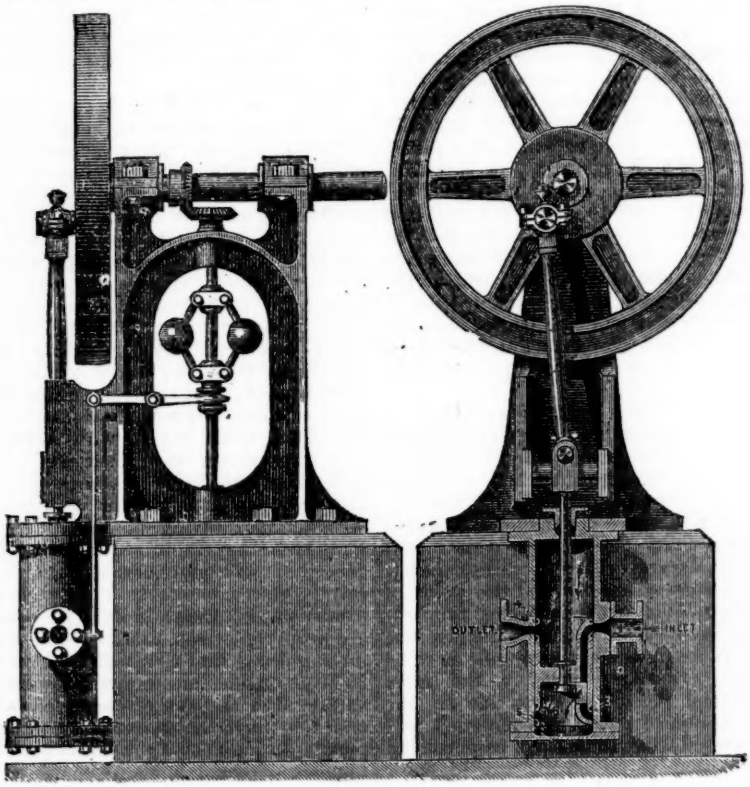
It is now, we understand, determined to exhibit the electric light to denote the night sittings of the Houses of Parliament on the summit of the Victoria Tower, instead of the Clock Tower, and the necessary machinery is in course of construction, under the direction of Captain Galton, of the Engineers.

# KING'S "VALVELESS" ENGINE.

From "Engineering."

Amongst the exhibits at the recent Conversazione of the Institution of Civil Engineers, which we are enabled to illustrate this week, is the valveless steam engine, of which engravings are annexed. This engine is one designed by Mr. H. J. H. King, of the firm of Messrs. H. J. H. King & Co., of St. James's Works, Glasgow, and its construction will be readily understood from the annexed section.




The piston, it will be noticed, is made very deep, and has 4 ports formed in it, 2 on each side. Of the 2 upper ports, one communicates with the cylinder above the piston, while the other forms the mouth of a passage leading to the under side of the piston, as shown. In the same way, of the 2 lower ports 1 leads to the lower end of the cylinder direct, while the other communicates with a passage leading to the upper side of the piston. The cylinder, also, has 2 ports formed in it opposite each other at the middle of its length, 1 of these being the inlet and the other the outlet port.

Supposing the piston to be at the bottom of its stroke, in the position shown in the section, the action will be as follows: The steam enters by the inlet pipe, 1, and passes down the passage cast in the piston, filling the cavity, 2, in the latter, and the clearance at the bottom of the cylinder. This admission of steam causes the piston to rise, when, with the proportions shown, the steam will be cut off at about $\frac{1}{8}$th of the stroke, the steam then expanding,

until at about $\frac{13}{16}$ths of the stroke, the bottom port, 5, in the piston begins to open to the outlet pipe and the exhaust commences. A little later, at about $\frac{7}{8}$ths of the stroke, the lower piston port, 3, begins to open to the inlet pipe, and steam is thus admitted to the upper end of the cylinder, causing the piston to perform its downward stroke. The exhaust ports are made sufficiently large to reduce the steam pressure in the cylinder to very little above that of the atmosphere before they close, the remaining steam being then compressed and assisting to fill the clearance spaces. In making high-pressure engines on this plan to run with a piston speed of 200 ft. per min., or upwards, Messrs. King & Co. make the width of the steam ports equal to about $\frac{1}{8}$th, and that of the exhaust ports equal to about $\frac{3}{16}$ths of the stroke; but, owing to the variation of piston speed at different parts of the stroke produced by the crank motion, each steam port will be open for about 44 per cent., and each exhaust port for about 52 per cent. of the *time* occupied by each revolution.

It may at first sight appear that an engine constructed on the plan above described must necessarily be a very wasteful steam user; but a little consideration will show that this need not be the case, particularly if the cylinder be steam jacketed. Its good performance will, however, depend greatly upon the capacity of the clearance spaces and the point of closure of the exhaust being properly adapted to each other, and to the pressure of steam with which the engine is to be worked. Speaking roughly, the most economical performance, as far as the consumption of steam is concerned, will be obtained when the ratio of compression is such, that if no steam was to enter through the supply port, the steam enclosed in that cylinder would attain the boiler pressure at the termination of the stroke. In this case, the steam used per stroke would equal that required to fill a length of the cylinder equal to the width of the supply port, and the work done per stroke would be approximately the same as that which would be developed by the same quantity of steam used in a cylinder without clearance and expanded the same number of times as in Messrs. King's engine. The principal effect of the early closure of the exhaust port during the exhaust stroke which takes place in Messrs. King's engine, is to reduce the power which it is possible to develop in a cylinder of given size. The greater part of the power expended in compressing the steam during the exhaust stroke, is given out again during the steam stroke, the precise proportion between the power absorbed and that regained depending, as we have explained on former occasions, upon the relative ratios of compression and of expansion during the exhaust and steam strokes.

Messrs. H. J. H. King & Co. inform us that the non-condensing engines constructed on the plans shown in our engraving, are found to compare favorably as regards economy, with ordinary non-condensing engines having single slides cutting off at about $\frac{5}{6}$ths or $\frac{3}{4}$ths of the stroke, a class of engine of which so many are now made for various purposes; while they have the advantage as compared with these engines of having no slide valve, eccentric, valve spindle, or valve spindle stuffing box, and they are, moreover, capable of running in either direction. When applied to steam cranes, therefore, small pipes, with cocks for admitting steam to either the top or bottom of the cylinder for starting, replace the ordinary link motion with a very considerable saving of cost. Messrs. King state that the arrangement we have described will give better comparative results with condensing than with non-condensing engines, and if the proportions are properly chosen, there is good reason for supposing that this will be the case. In large engines means are provided for varying the amount of clearance at will, and the ports instead of being cut completely through the cylinder consist of a number of small holes, over which the piston rings pass easily. Altogether the engine is a very simple and ingenious one, and we shall be glad to hear further particulars of its performance upon a large scale.

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Reports have been received from the United States expedition which is exploring the Tehuantepec Isthmus in Mexico, to discover a canal route between the oceans, that a practical route has been discovered. No particulars have yet been obtained, however

# ACCIDENTS TO RAILWAY STRUCTURES.*

Railway accidents may be roughly classified as follows:

I.—*Running off the track* from breakage of parts of engines or cars; breakage or displacement of rails; malicious or accidental obstructions on track.

II.—*Collisions* from disregard or misunderstanding of signals; overcrowding from badly arranged time-tables; misplaced switches; accident to train on one track throwing it in the way of train on the other.

III.—*Failure of structures* from decay or original bad design; shocks from breakage of machinery, causing trains to run off track while crossing, or from collisions on bridge.

It has been observed that the most disastrous accidents have resulted from an unforeseen combination of two or more of the above causes.

The late appalling accident on the Hudson River Railway is an illustration of this, as it was a combination of all three of the above principal causes.

The primary cause was the breaking of the axle under the oil car.

According to the evidence of Mr. Toucey, Superintendent of the Railway, broken axles have been known to run 20 miles before being discovered, "the frozen ground keeping it up; in this case it evidently dropped through the bridge."

The second cause, therefore, was failure of a structure from shock caused by breakage of machinery. This threw the car from one track over upon the other, and a collision resulted, aggravated in its consequences by the presence of petroleum, and from its being upon a wooden structure, which quickly burned down.

Much severe criticism has been passed upon the Company because "the safety signal," as it is said, "lured the train to destruction."

It appears to have been overlooked that the same unhappy result would have followed if the signal-lamp had been entirely removed, when winter changed the bridge from a movable draw into a fixed structure.

Moreover, a collision would have taken place on a fixed bridge where there never was any signal, if the broken car had happened to have crossed one. In fairness to the employees of the railway, the accident should not be attributed to a disregard or misunderstanding of signals.

The combination of a broken axle, a bridge, a car laden with petroleum, and an express train coming up at the same moment, were all required to cause this truly dreadful event.

The object of the present paper is merely to consider one of these points, and to discuss the questions whether bridges, as now constructed, are sources of danger, and, if so, can the chances of accident therefrom be reduced by different forms of construction?

It is believed that there is no instance of a bridge, designed by an American civil engineer, having broken down from bad design, or insufficient material, as did the Dee bridge in England, designed by Robert Stephenson.

All the bridge accidents in this country, it is believed by the writer (and if mistaken, he hopes some member will correct the statement), have occurred either from the falling of temporary trestle work, or from weakness caused by decay, or from sudden shocks occurring when trains have run off the track. Our bridges, both of wood and iron, are safe so long as the trains remain upon the track. How many of them are absolutely safe under all circumstances? If not, how can we make them so? or at least diminish the chances of accident? This is the practical question.

It was a practice in English bridge construction introduced by Brunel, and now falling into disuse, to make the platform of a bridge in the shape of a trough, which was filled with gravel or broken stone ballast, and the ties laid in it, just as on earthworks.

The reasons given by Mr. Brunel for this were as follows:

1. To enable the alignment and level of the rails to be maintained by the same men and with the same tools as on other parts of the line.

2. To prevent concussion when a train came upon a bridge, as there was no change in the nature of the support given the rails.

* From a paper read before the American Society of Civil Engineers by Mr. Thos. C. Clarke.

3. To prevent vibration being transmitted to the iron-work of the bridge.

4. In case of trains getting off the rails, to prevent their ploughing through the flooring.

5. To protect timber flooring from fire.

6. To provide for changes of length caused by temperature.

7. To increase dead weight on short spans so that there might be no jar from the rapidly applied load of a locomotive.

It was Brunel's belief that the cost of the extra material required to support the ballast was more than compensated by the above advantages.

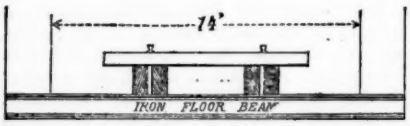


*Fig. 1. Section.*

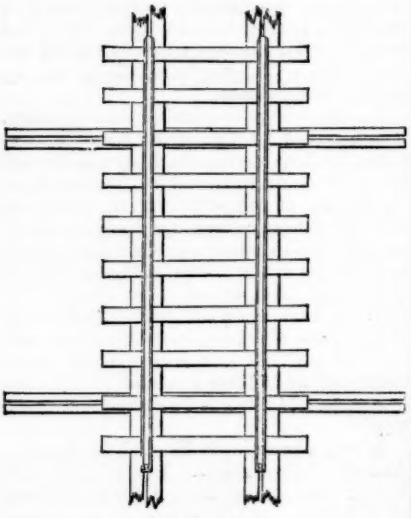

*Fig. 2. Plan.*

Most American engineers would say that the first object was of little consequence; that the second and third are equally well provided for by a wooden system of flooring; that to use ballast for the fifth would do more harm than good, because the timber and plank would rot unseen; the sixth can be accomplished more easily in other ways; and that the seventh had better be attained by making the iron-work heavier. The fourth, that of preventing trains ploughing through the floor, ought to be accomplished at any cost. But let us examine if there is not a better way.

The weight of the ballast itself averages about 500 lbs. per ft. run, and that of the additional parts of platform necessary to support it about 500 lbs. more. In other words, it weighs as much as the iron-work of an American truss bridge of 150 ft. span, or an English plate girder of 110 ft. span. This great addition of dead weight has prevented its adoption here, and caused its disuse in England.

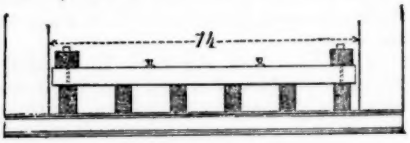


*Fig. 3. Section.*

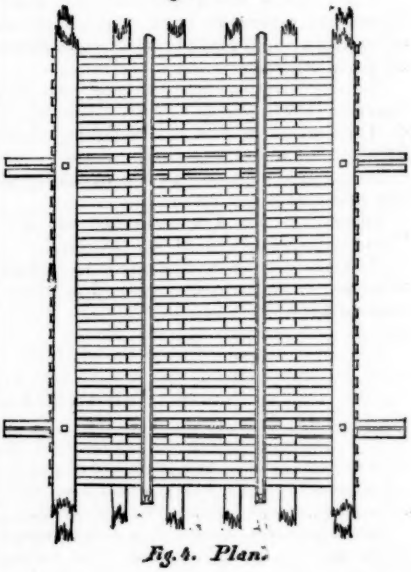

*Fig. 4. Plan.*

The object which it was intended to accomplish was excellent, and it is to be feared that this has been too much neglected in the rough and ready style of construction adopted in our earlier bridges at least.

If the train jumps the track while crossing, it falls through a space equal to the height of rail..... $4\frac{1}{2}$ in.
" " track stringer...12 "
" " cross tie..... $5\frac{1}{2}$ "

22

in. in all upon the floor beams, which, in most cases, would either be broken outright by the shock, or crowded apart by the wheels of the engine, so that it would drop through the bridge.

The arrangement of platform on most iron bridges is still more dangerous, as the floor beams, though of iron, are placed in pairs together, and from 10 to 15 ft. apart, so that there is nothing to prevent the engine from dropping between them if it once leaves the rails. This is shown in Figures 1 and 2.

There is a mode of construction shown in plan and section in Figs. 3 and 4, which is in use upon some of the Pennsylvania coal roads, which is much better provided to secure safety in case of trains leaving the rails.

The track stringers are numerous, and are strong enough to resist a severe shock. The ties are made of 4 x 12 in. plank on edge placed 6 or 8 in. apart, and blocked between every one, both at each end and under the rails. It will be observed :

1. That the distance that the wheels can fall cannot exceed the height of the rail or $4\frac{1}{2}$ in.

2. That the platform is broad enough to support the wheels even if the train is off the track.

3. That the ties are so close that the wheels cannot drop between them, and, being firmly blocked, cannot be crowded apart so as to leave a space through which a car or engine may fall.

In addition to this there should be heavy guard timbers, as shown, on each side, to prevent the engine striking the trusses of the bridge before its motion is arrested. There should also be a few planks spiked together lengthwise, so as to support the track in case of an axle or wheel breaking.

If such an arrangement does not insure perfect safety, it certainly diminishes the chances of danger far below those which are inseparable from the style of construction shown in the drawing, which it is believed is the style commonly used in this country.

As the one object of bridge building is to insure the safety of what is carried across the bridge, it would seem desirable that some of the superfluous talent which fills our engineering papers and magazines with elaborate calculations upon the strength of the parts of the main trusses of bridges, none of which were ever known to fail, should be diverted to drawing the attention of railway managers to a safer construction of the floor system than now prevails.

## SHOEBURYNESS EXPERIMENTS.

From "Engineering."

An interesting series of experiments was carried out at Shoeburyness recently, upon which occasion the capabilities of a new target, designed by the War Office authorities, and the Prussian field-gun recently presented to this country, were tested. The target is of unusually large size, measuring 48 ft. long by 9 ft. high. Although built up in one, it really represents two systems of targets. In one the armor plating is 8 in. thick, with a backing of teak 18 in. thick and a $\frac{3}{4}$ in. iron skin with iron ribs in the rear. In the other the front plate is 8 in. thick, and is backed by $5\frac{1}{2}$ in. of teak, behind which is a 5-in. armor plate backed with 6 in. of teak and a $1\frac{1}{2}$-in. iron skin. The guns brought to bear upon this compound target with the 9-in. Woolwich muzzle-loading rifled 250-pounder, and the 11-in. Woolwich muzzle-loading rifled 500-pounder gun. The 9-in. gun was directed against the 8-in. armored portion, and the 11-in. gun was laid against the target carrying the 13-in. of divided armor, the ranges being in both cases 200 yards.

Both guns penetrated the targets, the 11-in. weapon doing exceptionally good work in sending its projectiles through the 2 armor plates and backing of the second target. Both plates were cleanly penetrated, the puncture disclosing the fact that the metal was of splendid quality.

The second part of the programme for the day consisted of comparative trials with the nominal 4-pounder breechloading Prussian rifled field-gun, fired with 9 lb. cylindrical projectiles, against the English muzzle-loading 9-pounder and 16-pounder field-guns. The general results of this practice were that the English 16-pounder fired 25 rounds in 13 min. 30 sec., making 14 hits upon the target; the English 9-pounder fired the same number of rounds in 8 min. 37 sec., scoring 13 hits; whilst the Prussian field-gun fired a like number of rounds in 10 min. 15 sec., making 13 hits. Competitive practice was then carried out with the 3 guns against targets representing troops, with good results.

## A PROBLEM IN BRIDGE CONSTRUCTION.

By W. C. WILLITS.

It is proposed to determine the form of the upper chord of a trussed girder, loaded uniformly on either upper or lower chord, so that the lower chord being horizontal, the upper shall be strained uniformly along its entire length.

We will apply the principle of moments, adopting the following notation:

Let L = length of clear span.
" $d$ = lever arm of strains for any bay of upper chord.
" $d_1$ = lever arm of strains for central bay.
" N = number of bays, counting on lower chord.
" $l$ = length of each bay $\frac{L}{N}$.
" $n$ = No. of any bay counting from the right.
" $m$ = No. of the central bay.
" $s$ = strain on any bay in upper chord.
" $s_1$ = " central bay.
" $p$ = load on each bay.

*Case* 1*st*. A trussed girder as represented in Fig. 1. Uniform load on upper chord.

The moment of the forces which produce the moment of strain in any bay of the upper chord, are, the moment of the reaction of one of the supports, and the moment of the load between the support and the bay. Hence the moment of the strain on any bay of the upper chord about the vertex of the bay equals the difference of the moments of the other two forces about the same point.

We have, therefore,

$$s\,d = \frac{N\,p}{2}\,n\,.\,l - n\,p\,\frac{n\,l}{2} = \frac{(N-n)\,n\,p\,l}{2} \quad (1.)$$

which is a general expression for any form of upper chord; and this form moreover depends upon the values $d$ and $s$, either of which may be assumed and the other found.

If $d$ be made constant, it becomes a case of parallel chords, but if $s$ be made constant the upper chord remains to be traced, which is the problem proposed.

From Eq. (1) we have the strain at the centre

$$s_1 = \frac{(N-m)\,m\,p\,l}{2\,d_1} \quad . \quad . \quad (2.)$$

from which $s_1$ can be determined by the known data in every girder.

Substituting this value of $s_1$ for $s$ in Eq. (1), we find

$$d = \frac{(N-n)\,n\,d_1}{(N-m)\,m} \quad . \quad . \quad (3.)$$

this being the lever arm of any bay, it is the perpendicular distance from the vertex to the opposite chord.

Now, suppose L, N, $d$, and $l$, are known quantities.

The bay E F is parallel to the lower chord, and the points E and F are in the perpendiculars from the middle of the bay to K. F M = $d$, E K = $l$ and M K = $\frac{1}{2}\,l$; hence F K can be calculated.

The position of the bay F G can be determined by calculating $d$ for $n = (m-1)$, and describing an arc with K as a centre, and $d$ as a radius, then drawing from F the line F G tangent to it, G will be in the perpendicular G N at the middle point of K Q.

For the next bay calculate $d$, when $n = (m-2)$, and proceed as before, each succeeding bay being determined in the same manner.

To determine the length of the bays and struts. In the right triangle F M K, F K and the angle $a$ can be determined from the given data; then, in the right triangle F K P, P K and F K are known, P K being perpendicular to F G and equal to $d$, when $n = m-1$. From this triangle $a$ can be computed; the sum of $a$ and $a_1$ is equal to the angle which the bay F G makes with the vertical.

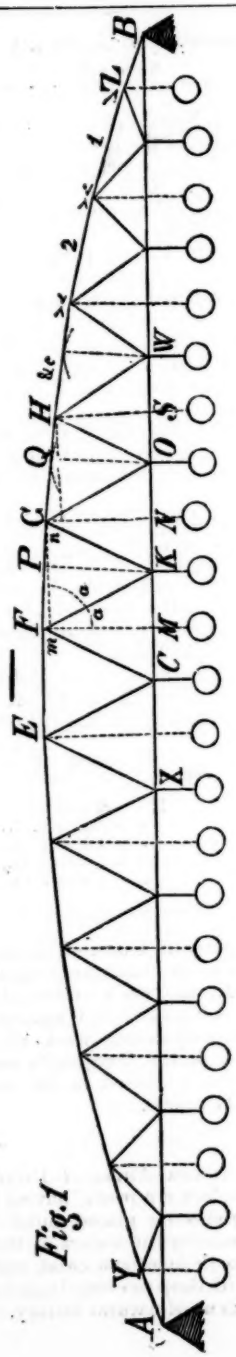


Fig. 1

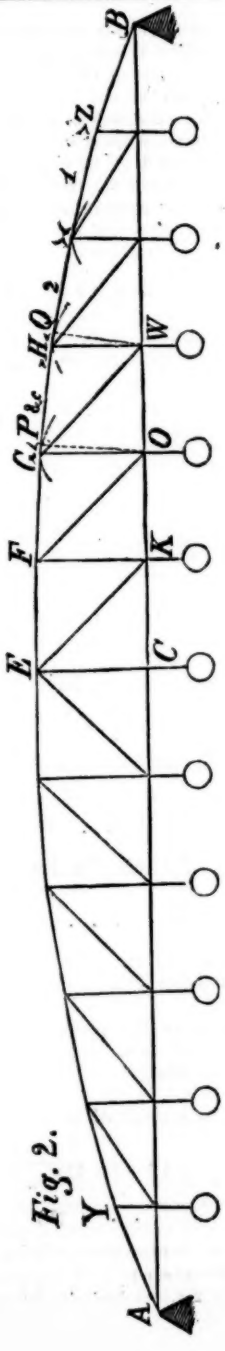


Fig. 2.

Draw $m$ G parallel to A B; $m$ G is equal to $l$. In the right triangle $m$ F G, the angle F and the side $m$ G being known, F G the bay and F $m$ can be computed. If from M F we subtract $m$ F there will remain N G, from which we can solve the right triangle G K N in which G K = G O. In like manner we can find H S, H O, H W, and the remaining struts and bays.

The numerical values of $d$ are now readily determined.

If $l = 120$, N $= 12$, $l = 10$, and $d = 10$, then by substituting in Eq. (3), we have

$$d = \frac{(N-n)\,n\,d_1}{(N-m)\,m} = \frac{(12-n)\,n\,10}{(12-5)\,5} = \frac{60\,n - 5\,n^2}{18}$$

If $n = 6$, $d = d_1 = 10$.
$n = 5$, $d = 9.7 +$.
$n = 4$, $d = 8.88$.
$n = 3$, $d = 7.59$.
$n = 2$, $d = 5.50$.
$n = 1$, $d = 3.05$.

It should have been remarked before that the upper chord in both figures extends from Y to Z, and that $n$ is determined by counting as the numbers 1, 2, etc., indicate.

*Case* 2*d*. To solve the problem of the girder Fig. 1, when the load is on the lower chord.

Taking the moments, we have

$$s\,d = \frac{N-1}{2}\,n\,l\,p - (n-1)\,p\,\frac{n\,l}{2} = \frac{(N-n)\,n\,p\,l}{2} \quad (4.)$$

and from Eq. (4) we have for the strain at the centre,

$$s_1 = \frac{(N-m)\,m\,p\,l}{2\,d_1} \quad . \quad . \quad (5.)$$

Substituting this value in Eq. (4), we have

$$d = \frac{(N-n)\,n\,d_1}{(N-m)\,m} \quad . \quad . \quad . \quad (6.)$$

which is the same form as Eq. (3), and the discession from this point is as before.

*Case* 3*d*. To solve the problem for the trussed girder of form represented in Fig. 2; the load being on either upper or lower chord.

From the principle of moments we have

$$s\,d = \frac{N-1}{2}\,p\,n\,l - (n-1)\,p\,\frac{n-l}{2}$$

$$= \frac{(N-n)\,n\,p\,l}{2} \quad . \quad . \quad . \quad (7.)$$

the strain at the centre then will be

$$s_1 = \frac{(N-m)\,m\,p\,l}{2\,d_1}; \quad . \quad . \quad (8.)$$

by sustituting in (7) we get

$$d = \frac{(N-n)\,n\,d_1}{(N-m)\,m} \quad . \quad . \quad . \quad (9.)$$

Let L N and $d_1$ be given. The bay E F is parallel to the lower chord and is equal to $l$. F K is perpendicular to it and equals $d_1$. K O $= l$ by construction; from which data we can find F O and the angle F O K.

The line P O is perpendicular to the bay; F G by construction is equal to $d$, and is calculated from Eq. (9), by making $n = m - 1$. G is in F P and a perpendicular to A B at O. In the right triangle F O P, F O and O P are known, hence the angle O F P is readily computed.

In the triangle F O G we have the angles at F and O and the side F O; we can therefore determine the bay F G and tie G O.

From G O and O W (which equals $l$) we can find G W.

The method of finding the remaining ties, bays, and struts, is sufficiently explained in the foregoing. The parts on the left are of course duplicates of those on the right hand.

The numerical values of $d$ for L $= 120$, $d_1 = 10$, N $= 12$, $l = 10$, are as follows:

Substituting in Eq. (9) where $m = 5$, we have

$$d = \frac{(12-n)\,n\,10}{(12-5)\,5} = \frac{24\,n - n^2}{7}$$

If $n = 5$, $d = 10$.
$n = 4$, $d = 9.14$.
$n = 3$, $d = 7.71$.
$n = 2$, $d = 5\ 71$.
$n = 1$, $d = 3.14$.

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Omnibuses in Paris.—The revenue of the Parisian Omnibus Company is reviving. In the week ending June 17, the receipts were £12,836, against £17,958 in the corresponding week of 1870. The number of the Company's omnibuses at work was increased in the week ending June 17 to 500.

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The North American Pacific Coast.—Professor Agassiz, having had a coast survey steamer placed under his control, is examining the waters of the Pacific on the North American coast, and in connection with deep sea soundings he will collect specimens of natural history.

# RESTORATION OF THE PLACE VENDOME COLUMN.

From "The Engineer."

Already the restoration of this column has been promised by the *de facto* Government of France. It is certain that the fallen monument could not be permitted to remain, a boast for the Communist, and a reproach to France, if so regardless of her own historical renown.

The *mode* of restoration must therefore soon come up for consideration; we therefore offer no apology for offering to our neighbors a suggestion as to this, in our capacity as exponents of British engineering.

At the date of its construction there was, perhaps, no alternative but that of clothing externally with bronze an interior core of masonry. Wholly of bronze the column could not be, iron was dear, and its manufacture in France little advanced; and France herself, relatively to even her now immediate future, was poor. Had it not been for this heavy and shaky stalk of soft masonry inside, the destroyers might have found their task, of *pulling* down at least, a more difficult one. In a word, the structure, taken as a whole, was a weak and rickety one, easily cut through in part, and then requiring little force to bring it down.

What we have now to say, then, is, let no masonry be employed in its reconstruction. Let the re-elevated column consist of a conico-cylindric shaft of boiler-plate work in 2 skins, an outer one adapted in diameter, taper, and contour, to the reception of the bronze spirals, and an inner one quite cylindric and prepared to receive a cast iron spiral staircase from bottom to top. Let those 2 great tubes be stiffened and kept concentric by a system of vertical radial ribs, also of boiler-plate work. The strength and *stiffness* of such a structure, as is well known from our iron lighthouse experience, is enormous. Socket the lower part well into the masonry filling of the square base, and also for some feet in depth down into the solid masonry of the foundation, and prepare the top for the reception of the capital, dome, and statue, as to the particulars of which we need not expend words.

The bronze spirals of *bassi relievi* should be *hung* on to the external iron tube by *boutons*—that is to say by bolt clamps, suitably designed to allow for the difference in expansion and contraction between the wrought iron of the less exposed tube, and the fully exposed bronze exterior through the whole range of the climate of Paris. In this there is no difficulty either, so we shall not go into details, but merely remark that upon such an iron surface many of the present spiral *plaques* of bronze—of which nearly the whole are stated to have been now recovered—may easily be restored to their places without their fractures being visible from below; those broken into fragments must, of course, be recast.

Now, what are the preferential advantages of this method over that of restoration, as at first, with a masonry core? They are—if we do not greatly err—a considerable saving in total cost, great rapidity of execution, no scaffolding being necessary at any stage of the progress; a far more stiff and workmanlike job in the end; the capability of using once more many of the fractured bronzes, which otherwise must be recast; an enlarged interior cylindric area for the spiral staircase, thus rendered more commodious; and, finally, the moving with the times—if that be worth anything—in thus employing metal, in place of masonry, in in union with another metal, the evils due to which we lately described.

One caution we may be permitted to give. A wrought iron interior structure, if consisting of thin vertical and diagonal members, a pair of lattice tubes in fact, will here not answer, though probably such would first be thought of by the inexperienced, as saving much material needful for the double tubes. Such a construction would probably be *strong* enough, but would be quite deficient in the necessary amount of *stiffness*. A remarkable instance of this became well known amongst ourselves some years ago. The water towers, originally designed for the Crystal Palace, consisted of vertical, horizontal, and diagonal members of cast and wrought iron, and were found to rock to and fro so dangerously that the late Mr. Brunel was employed to redesign them, and he produced *stiffness* by the introduction of thin cast iron rectangular panels

between the vertical members and the horizontal ones of each story, thus approximating to a tube in the outer shell. The column, reconstructed as we have suggested, might no doubt be shattered and blown down by gun-cotton or picrates, but it would probably overtask the engineering of some future Commune to *pull* it down.

France, amongst her many able engineers, possesses one pre-eminently fitted to design and carry out this work in the Place Vendome, viz., Monsieur Léonce Reynaud, chief engineer for the lighthouses of France, whose iron tower for the *phare*, upon the Douvres Rock, was a conspicuous object of the Parc at the Great Exhibition of Paris in 1867.

## DUTCH INDUSTRY.

From "The English Mechanic and World of Science."

Dutch industry is scarcely less proverbial than Dutch cleanliness and Dutch art. Nor is the special repute implied by the title undeserved by a nation which has almost created a country for itself; barring out the sea, draining lakes, constructing canals fit for ocean traffic, and converting sand-hills into gardens. An opportunity of contemplating the peculiar genius and habits of this remarkable people is now afforded by the tardy publication—after 2 years' delay—of the Hon. T. J. Thurlow's special report upon the Amsterdam Exhibition. Mr. Thurlow, acting in concert with the able British Commissioner, Mr. P. L. Simmonds, who not only managed the English department, but had charge, as well, of all the scientific details, takes a thoroughly practical view of his subject, which is divided into 7 sections, not all of which fall within our scope. We propose to regard the Dutch, as represented by their industry, from a domestic and artificer point of view—in their homes and at their work; because, although no strict parallels of comparison can be drawn between them and the English of similar classes—owing to local circumstances—they may still teach a few lessons to the world around them. That, indeed, was the grand object of the Exhibition in 1869, and this important volume gives the entire results, faithfully and minutely. The Dutch, in their display, put the dwelling-house foremost, as the first requirement of civilized society; but they included, also, workingmen's institutions and the materials of building. Their plan consisted in reconciling the needs of the inhabitant with the interests of the proprietor, and the methods adopted deserve attention, it being premised that they apply to a very peculiar region. Holland contains no cities, like London, in which a square yard of freehold ground is scarcely less than an estate; but, on the other hand, most of her solid soil is artificial, possessing, therefore, an artificial value. Still, even this circumstance prevents the spreading of her towns over indefinite areas, so that the artisan, at his employment, can never be very distant from his home, whatever may be the case with the agricultural laborer. In the first place, nothing is more odious to your Dutchman than a "colony house" or "perpendicular street," as it has been called, a lodging of many floors, with a staircase which is a public thoroughfare, a common pump, a common well, a common cellarage, conducing to quarrels, and the destruction of real domesticity. But, hitherto, the poorer population of Dutch cities, notwithstanding all our romantic ideas on that topic, illusorily illustrated by the show village of Broek, near Amsterdam, which is forever clean and never inhabited, have been extremely ill-sheltered. In the capital they live, for the most part, in cavernous holes below the water level of the canals, always damp, often flooded, and condemned by medical science as most unhealthy. Since the Exhibition, strenuous exertions have been made to provide them with better homes, and much in this direction has been done. We begin with the single-story buildings. They have two rooms, a garret, and a cellar, besides an out-house; their cost is £92 each, and the rent about 2s. a week. The double-storied cottage has two rooms on the ground, with a bed recess in one, two rooms above, and a loft with a window in it; a ladder leading up, a stove, a chest, which is a fixture, a stone sink, and a

dresser, and water is laid on. These are far more popular than the four-house blocks on the Hague and Haarlem models, though their accommodations are infinitely superior. In these, the ceilings are composed of wood with a zinc lining. They let at from 2s. 6d. to 3s. a week, and the calculated net profit is 7 per cent. Even better are the cottages built by the Dutch Carpenters' Society. They are somewhat crowded with conveniences, so to speak; but the means of ventilation would be perfect were it not that the immediate instinct of a Dutch housewife is to stop up every aperture through which fresh air can enter or foul air escape. But the model of models is that of Dort, a village made, to all appearance, expressly for artists to study. They are double, facing east and west. Each has two floors, completely separate, the lower entered through a porch and door level with the garden, the upper approached by a flight of exterior steps. Thus, 4 families may inhabit the same building, as though the dwelling of each were completely detached. They may partition the cellars and lofts, or one may agree to take the loft, and the other the cellar, by arrangement. They need never meet; there need never be any collision between them; all the appurtenances are distinct. We noticed in these pretty little abodes, an air of great comfort and solidity. They are built of hard yellow brick and roofed with blue tiles; the flooring is of thick wood or strong beams, with good stucco ceilings underneath, and the cellars and kitchens are tiled. One iron bedstead, secured to the wall, is provided by the proprietor, and wooden bedsteads are altogether forbidden. Including all expenditure, even that of a bridge across the neighboring canal, a rental of half a crown a week for each leaves a profit of exactly 5 per cent. The Dutch resemble the English in one important respect. The wives of our agricultural laborers, according to the highest authority prefer having all the rooms on one floor. They say they are thus better enabled to look after the sick and the children. The Dort model, though of 2 stories, practically answers this end, the only difference being the necessity of a a gate or half-door in the porch of the upper flat. In all these structures, humble though they be, ample space is afforded for the storage of wood, coal, and those dried provisions in which your Hollander so characteristically delights. Curiously enough, however, it was left for an English firm—Messrs. Engert & Rolfe—to teach the Dutch how they might preserve their homes from damp. In Holland, where the foundations of all houses are literally laid in water, and where the common Archimedes screw pump has to be kept constantly at work while digging and building foundations, the invention of fibrous asphalt, to be laid between the courses of brickwork, preventing the passage of moisture upwards, is immensely appreciated. It seems stranger, too, that the Dutch rely upon us, principally, for their drainage-pipes, as well as for their apparatus of water supply. Now, having indicated the nature of the Dutch working man's dwelling, under the new order of things, and in the suburbs, let us see how he fills it with comfort. His principal idea of furniture, let it be said at once, is an abundance of pots and pans—for milk, for "roasting," for washing, for coffee, for filters, for pepper, mustard, sugar, and soap, for tea, eggs, and Schiedam. He loves, in his cottage pottery, to indulge in mournful mottoes. We once, by a Friesland fireside, after draining a deep mug of the purest Geneva, were warned at the bottom of it by the words, "Death must come." It is all plain work, resembling in no respect the tinted wares of France, Belgium, and Austria. So much for the "dresser" and the table. In the fire-place or, rather, stove, is chemically-prepared peat. In the kitchen is more hardware than could have been imagined within those limits—laundry irons, heaters, wash-tubs, and mangles, all seeming to be folded away when out of use. The bedding is of Kapok, a silky fibre, from the seed gourd of a tree known only in the Indies. From the seed is obtained oil, and with the refuse cattle are fed. Neither moth nor vermin will attack this material, and hence the Dutch are helped by nature to keep their households wholesome. But it is in his bedstead that the Dutchman exhibits the greatest pride. The niche in the wall is now almost universally condemned on sanitary grounds, throughout Europe. So the Dutchman puts his bed-room in a box, with all its accessories, and even contrives, sometimes, that a part of the ceiling shall descend at night in the form of a large flat

couch. He is fond of lamps, moreover; but he cares little or nothing for the paper hanger's trade. His clocks were once popular beyond the limits of the Netherlands; but now they are elsewhere out of date, superseded by English and United States manufactures. But nobody could have seen the peasantry flocking in and out of the Amsterdam Crystal Palace, without appreciating the importance of the white wooden tubs in the cottages, and being aware of the national devotion to starch. Of course, it is rice starch in Holland, and Mr. Simmonds, in a paper quoted by the Hon. Mr. Thurlow, shows how vast this manufacture is becoming. This leads to the department of clothing, and it may be noted that a Dutchman regards a tobacco-box as an article of wearing apparel. He is great in waterproofs, in all varieties of open air and sea-faring attire; he is supreme with brown duffles to keep the damp from the skin, as he is with oil from fir-cones to cure rheumatism, and pine-juice lozenges to strengthen the lungs, in his vaporous country. So, too, with wooden footgear, garden-shoes, swamp-shoes, sand-shoes, mud-boots, iron-workers' boots, and pigs' leather gaiters for well-sinkers. We do not dwell, passing from these classes to that of food, upon the peculiar nutriment affected by Dutchmen, since it lies beyond our purpose; but pass on to the collection of tools, very characteristic of the country—tools for gardeners, farm-laborers, dyke-workers, and boat and ship builders, and nets and tackle for fishermen. The Dutch have a strange objection to improvements in these respects, and their implements are, therefore, for the most part, of the most homely and ordinary kind. Their fishing-tackle is wonderfully varied in material and construction; but it is nearly all old-fashioned. Their dyke-workers' apparatus dates from beyond the Great Revolt. Their gold work and diamond cutting is done upon ancient methods. Their millstones, however, and who so great as authorities on the making of mills as they? exhibit continual improvement, and their coopery is magnificent. Oddly enough, however, they buy their best carpenters' benches from Austria, and carpentering is among the chief of industries in Holland, notwithstanding that there is not a wood worth speaking of in the entire region. It is the Rhine which brings them their enormous supplies of deal from the Black Forest. And what are the facilities afforded to the Dutch workman for making progress in his craft? There was at the Exhibition a large variety of models in various materials—wood, cork, card-board, and metal, including many of the celebrated buildings and most of the historical models in the Netherlands; with steam and water mills, locks, docks, and shipping; the drainage systems of towns and districts, foundations, staircases, gem-cutting engines, boring machines, and so on; with drawings from nature and from copies; and it is worth remarking here, that by the Dutch law there must be at least one technical school to every 10,000 of the total population. We agree with the report in believing that, in its practical results, the Amsterdam Exhibition was of exceeding value. To quote only one example, satisfaction was loudly expressed by the Dutch artisan at the opportunity afforded him of comparing, side by side, the tools of England with their Belgium imitations, the manufacturers of which frequently do not stop short of counterfeiting the trade-marks of the best known Sheffield firms. The result of the comparison was generally admitted to be in favor of British hardware, over the Continental manufacturers. "More than one Dutch carpenter," says Mr. Thurlow, "informed me triumphantly that his study of the two would enable him thenceforth to distinguish the real article, from its make and general cut, from the crafty imitation." They have much to learn from us, but we, also, have not a little to acquire, in course of time, from them, as they who study the official report will testify. Holland, as we have said, is in many senses—in a sense applying to no other country of the world—a creation of human industry. *Luctor et emergo* is its proud and legitimate motto. It has been recovered from the sea and enriched by the rivers. The patient people still continue to contend with the elements along their maritime and inland water boundaries, in the foundations of their cities; in the manufacture, so to speak, of cultivable soil for their fields and gardens. They are slow, but they never cease progressing. They are not particularly inventive, except in matters of sea walls and windmills; but they are apt at mechanical adaptation.

Steam power is less available for them than for other nations, owing to the paucity of fuel, because where peat is dug lakes are formed, which is a check upon the process, and coal is comparatively dear, because it has to be bought in Belgium or England. In point of fact, there was hardly any Dutch steam machinery in the Great International Exhibition at Amsterdam.

But in their mighty drainage works they have found this species of power to be essential. In one place, 3 English-built engines superseded 140 windmills, and there was no question about the economy of the change. The Netherlands farmers, who reap the benefit of these reclamations, are still, or were until 1869, very imperfectly acquainted with our best instruments of cultivation — clod-crushers, drills, manure distributors, and dibbles; yet they understand the land they have to till, and upon the whole, their management of it and industrial life in it, are studies in civilization worth the notice of all practical minds.

## THE TRANSPORT OF EXPLOSIVES.

From "Engineering."

A question of considerable importance to all those who are interested in tunnelling or mining operations is now being warmly discussed in certain quarters. This question has reference to the propriety of the Government relaxing some of the more stringent clauses of an Act of Parliament passed in the year 1869, and which prohibits the importation, and restricts and regulates the carriage, of nitro-glycerine and all substances containing it. The Act was framed and hastily carried through Parliament at a time when carelessness in the transport and handling of nitro-glycerine had caused several fearful accidents, both at home and abroad. Unquestionably this stringent piece of legislation was much needed at the time, and it afforded protection to life and property which had previously been much jeopardized. Nitro-glycerine is confessedly a highly dangerous substance; but it was such an invaluable material in mining operations that great risks were run in order to obtain it, as by its use much labor was saved, and much gain resulted. Nor was the running of these risks altogether unreasonable or inexcusable. By the use of nitro-glycerine, mines could be worked which were well nigh being given up, from the excessive cost of blasting with gunpowder. But still the State was perfectly justified in stepping in to protect the subject against himself as well as against his neighbor. Since the passing of the Nitro-glycerine Act, however, science has advanced, and we now have explosive compounds as powerful as nitro-glycerine, and yet absolutely safer than gunpowder. Such are dynamite and lithofracteur, the former a well known explosive, eminently satisfactory, alike in force and safety, and the latter, though less known, a powerful and safe material. On pages 343, 356 of the present volume will be found details of experiments with this material which proved its harmlessness under all conditions except those of actual work, although it contains a large percentage of nitro-glycerine.

But the satisfaction of a score or so of scientific men upon this point was not the aim and end of the experiments, nor of those connected with them. Having publicly established the safe nature of the material, it was desired to place the facts before the Secretary of State for the Home Department with a view of obtaining permission for its introduction into this country free of the more prohibitory restrictions of the Nitro-glycerine Act. With this object a deputation consisting of nearly 20 members of Parliament, and a number of other gentlemen representing mining, scientific, and commercial interests, waited on Mr. Bruce on this day week, and were received by him in the House of Commons. The deputation was introduced by Mr. S. Holland, M. P. for Merionethshire, who stated the object of the application, which was in effect to obtain permission to import lithofracteur into England, and also to manufacture it here under proper restrictions. Mr. R. S. France—the gentleman at whose quarries the recent lithofracteur experiments took place—explained to Mr. Bruce the nature and results of those experiments. He

also urged the desirability of having an explosive material possessing such power and safety as lithofracteur freely introduced into England for mining and quarrying purposes. A large shipowner, Mr. Houlder, who was also present at the experiments, stated that he was perfectly satisfied with the safety of the compound, and expressed a hope that in the interests of commerce the heavy prohibition at present existing against its transport, would be removed. An observation from Mr. Bruce upon the peculiarity of the name of the material, led Mr. France to remark that Messrs. Krebs, the manufacturers at Cologne, intended to alter the name to that of "Krebs' explosive." With regard to the application, Mr. Bruce observed that his personal opinion in the matter went for nothing; he could only act upon that of his scientific advisers, inasmuch as the responsibility would rest upon himself. The statements made, taken by themselves, appeared very conclusive, and he was most averse to interfering with the use of anything which was a safe and powerful explosive. His object would be to encourage its manufacture, and he would have the matter looked into at once.

Of course there is nothing conclusive in all this, nor could it be expected that there should be. But the position matters have assumed with regard to the introduction of safe explosives is hopeful for the promoters of the movement, and in the interests of commerce and progress we are glad to see it. There can in fact now be no valid reason why the permission sought should not be granted. The Nitro-glycerine Act specifically states that if it is shown to the Secretary of State that any substance having nitro-glycerine in any form as one of its component parts can be safely imported, he may authorize its introduction into the United Kingdom. That dynamite and its kindred materials can be safely imported we have no doubt whatever. In support of this opinion we have but to refer to their extensive use on the Continent and to the Shrewsbury experiments. We therefore see no reason why Mr. Bruce should not grant the permission requested, and thus relieve those interested in mining and quarrying from the hardship they now suffer in not being able to avail themselves of materials eminently adapted for their purposes.

## PRESERVATION OF SHEET-IRON VESSELS.

By C. WIDEMANN.

From the "Journal of Applied Chemistry."

The sheet iron used in naval constructions is very heterogeneous, from which electrical currents are generated, soon causing the decomposition of the water, or of the salts held in solution in it; thus quickly destroying the iron sheets by oxidation; the part that first become damaged is where heavy deposits of shells and weeds accumulate, which impede the speed of the vessels.

MM. Demance and Bertin have endeavored to prevent this destructive oxidation, the original cause of these deposits. By their peculiar arrangement the whole vessel is transformed into a kind of large Volta cup battery; large zinc holders in the shape of tanks or cylinders, are placed against the internal sides of the vessel; these holders are kept in perfect electrical communication with the frame and outside portion of the vessel by means of rivets, etc., or any other suitable connections, and they are daily filled with salt water; blades of zinc crossing each other, and passing over the outside of the vessel, are also connected with the holders; by the oxidation of the zinc these charge it with negative electricity, transmitting it by conductibility to the iron of the vessel, which thus becomes similar to an immense electrode charged with this negative fluid.

The authors at first believed that the iron thus coated by an envelope of negative fluid would by that reason acquire a certain electrical polarization, and thus be preserved from the action of the electro-negative bodies, either contained in the atmosphere or the sea water; the negative fluid was to disappear in a regular way in the water, and the positive fluid of the liquid slowly disappear in the damp atmosphere, and this action taking place independently of the currents in the in-

side of the vessel, between the liquid contained in the tanks, and the iron works of the vessel, connected as it was by rivets, etc.; but the vessels thus armed have not proved a success, the interior was well preserved, but the outside very soon showed signs of oxidation.

MM. Demance and Bertin then continued the action of the holders by means of a small zinc blade fixed on the exterior of the vessel, in electrical communication with the tanks, and dipping in the sea water at its lower end. Experiments made under these circumstances have proved a complete success; and vessels thus protected have, after long voyages, shown no signs of oxidation, while other vessels, within the same period of time, and under the same circumstances, have been thoroughly oxidized.

These experiments suggested to M. Schussler, of the Metropolitan Gas Works, and the writer, the idea of applying this principle to gas holders used in gas works; these holders are usually made of sheet iron, and, as the Metropolitan Gas Company used the salt Hudson River water in their gas holder tanks, the oxidation was very rapid, destroying the iron, and preventing the coat of paint from adhering to the sheets.

In our first experiments, we introduced small pieces of sheet iron into different liquids and water at different degrees of strength as to the quantity of salts dissolved in them; the sheet iron very soon became oxidized, and having applied the principle of MM. Demance and Bertin, by connecting the piece of sheet iron with a small blade of zinc, the oxidation was prevented, and this piece, although having been in brine for over 7 months, has not yet shown the least sign of oxidation; I believe that the same principle could be applied to all iron work exposed to sea water, or even in moist soil; gas posts in streets might also be thus prevented from oxidation.

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## THE SELECTION AND USE OF STONE FOR ENGINEERING AND ARCHITECTURAL PURPOSES.

By MR. ARTHUR C. PAIN.

From "The Building News."

The use of stone dates back to the earliest of times, at first for sling stones, arrow and spear heads, and in the catapult.. It is not as a weapon of offence, however, that I propose to treat on it to-night, but principally as a weapon of defence against the two elements, fire and water, in the construction of breakwaters, docks, and public and private buildings. For these purposes it was the first material used, and although various artificial materials, such as brick, terra cotta, cement, concrete, etc., have been invented, and used with varying success, still it holds its own against them all; neither can we be surprised when we consider its great natural advantages. It is easy to hand, no making, baking, burning, or mixing, to be done, and widely spread in large and small quantities of all qualities all over the world. In the construction of breakwaters, piers, and arches of bridges, river-walls, lintels over wide spaces or for heavy cornices—indeed, wherever strength and weight are required, or heavy blows or weights have to be resisted, it is unequalled. It can be had of any size or shape and of any quality, from the great blocks of rough hard granite, tons in weight, used in sea defences, down to the fine even grain of the Oolites, some of which are capable of being carved almost as elaborately as wood. Some have argued that stone is not so durable as brick or terra-cotta, or indeed, cement. I have no desire to dispute the powers of lasting of these materials when good. But surely our own old cathedrals and castles, to say nothing of the Pyramids of Egypt, supposed to have been built 1,600 years B. C., are sufficient proof to show that where reasonable care is exercised in its selection, it is good for "all time." In all materials there are various qualities, and it is no argument to take the best example of say cement work, and compare it against the worst of stone, and then contend that cement dressings are as good as stone. Where clay is plentiful, brickwork is generally cheaper than stonework; but if much labor is required, as

in axed arches or moulded and rubbed brickwork, stone can be used generally quite as cheaply.

If we take terra-cotta, there is no economy in its use, unless you make a great number of articles of the same pattern; even then, the burning twists and warps it so, that if of any size it is very difficult to get the work true; whereas stone can generally be had soft or hard, of various colors, and of any size. Some short time ago a gentleman writing on stone endeavored to prove that stone used out of the district where it was quarried did not stand so well as in the neighborhood, because the foreign climate did not agree with it. Nothing can be more absurd or illogical. Why should a piece of granite from Guernsey decay faster if used at Aberdeen, instead of at St. Peter's Port? How such an idea could ever have been seriously promulgated, all reasoning persons must be at a loss to understand.

Stone having so many advantages, and being so much used, it is surprising that it has not been made a branch of study in the education of the engineer and architect. The remarks of the late Sir H. de la Beche on this point, although written upwards of 30 years ago, are still applicable to the present time. He says: "There was much excuse for the accidental durability of the stones employed in public or large private edifices in the former days when the mineralogical structure of building materials was so little understood, and the architect of those times could not always have churches or castles before them, from which they might judge of the relative durability of any stone they were about to employ, the quarries opened by them being also the first worked, to any considerable extent."

The architects and engineers of the present day cannot, however, avail themselves of these excuses, for the necessary chemical and mineralogical knowledge is readily acquired, and the number of public and private edifices of various dates scattered over the country is so great that the relative durability of the materials employed in their construction can easily be seen. It is, nevertheless, well-known that with some few exceptions the mineralogical character of the stone employed in public works and buildings has hitherto received little attention from either architects or civil engineers in this country, more especially from the former, whose value of a material seems commonly to have been guided by the opinion of the mason. Now the mason seems almost always guided in his opinion by the freedom with which a stone works—no doubt an important element in the cost of a building, but certainly one which should not be permitted to weigh heavier in the scale than durability; and hence many a fine public or large private building is doomed to decay, even in some cases within a few years. It is a common practice for young men who are intended to be brought up to be civil engineers to serve for some time in the works of a mechanical engineer, with a view to learn the uses and properties of metals. So with those intended for the architectural profession; they are taught first to be carpenters or joiners, to learn the uses and properties of timber. Why should not a young man who is desirous of entering either profession, also learn some knowledge of quarrying and masonry by practical experience in the quarry and at the banker? Surely stone is as important a material as either iron or wood in the construction of engineering and architectural works? Perhaps no more practical engineer ever lived than Thomas Telford, and he began life as a stonemason in Scotland. The importance of a proper knowledge of the selection and use of stone to engineers and architects can hardly be overrated. Indeed, some idea of its commercial importance may be gained by a knowledge of the fact that the value of the stone raised every year in the United Kingdom is said to be nearly if not quite £5,000,000. I shall, therefore, without further comment, commence the first part of my paper—namely,

### THE SELECTION OF STONE.

Geologists tell us that the great divisions of rocks are classed according to the fossils that are found in them, and by the term fossil must be understood to mean any body, whether animal or vegetable, buried in the earth by natural causes. Rocks known by this test are termed generally aqueous, sedimentary, or fossiliferous, supposed to have been formed by the action of water on the earth's surface; these are stratified or divided into layers. From these rocks are raised most of the principal building stones, certainly those easiest to work. Other rocks are classed

as volcanic ; these are, for the most part, unstratified and devoid of fossils ; they are supposed to have been forced up through the various overlying strata, and flown into and over the same by the action of fire. They are known generally by their columnar and globular structure. These produce not only building stone, but stones which are used for ornamental purposes more than any other kind of rock. Further, we have Plutonic rocks, highly crystalline, and destitute of organic remains. They are supposed to be all of igneous origin, but to have been formed under great pressure ; they have been melted, but cooled and crystallized very slowly. They differ from the volcanic by their more crystalline texture, and by the absence of pores and cellular cavities. From these rocks we have some of the finest, hardest, and most durable of building stone. Lastly, we come to the metamorphic or stratified crystalline rocks. The origin of these is more doubtful than any of the other three classes ; they contain no pebbles, sand, or angular pieces of stone or traces of organic bodies, often as crystalline as granite, yet divided into beds. They are supposed to have been deposited from water, but afterwards altered by subterranean heat so as to assume a new texture. Building stone is not raised so largely from these rocks as from the others. Many of the white marbles are, however, metamorphic. Nearly all the various systems embraced under the name of aqueous rocks produce sandstones and limestones of various kinds. It is important to remember this, as very frequently a stone is called oolitic or carboniferous from the system to which it belongs,when, perhaps, to the eye, it might not exhibit the more particular characteristics of the formation. In a paper read by our President in March, 1862, he treated all the various building stones in each geological formation. I propose, therefore, to make my remarks more on the practice than the theory of the selection and use of stone.

In selecting a quarry from which to get the stone best suited to the purpose for which you want it, great care is required. Having first satisfied yourself that stone of the size required can be obtained, and at a reasonable price, the next and most important step of all is to find out if it is a durable stone. Too much weight must not be placed on the assurance of the quarrymen that the particular bed which is the cheapest for them to get is the "best," and, by that word, I mean the most durable ; not, as it is often understood amongst quarrymen and masons, the prettiest-looking stone and the easiest to work. Again it does not follow that because certain old buildings, small or great, in the neighborhood have lasted well, therefore all the quarries in the neighborhood produce the same stone. In some cases the best beds have been worked out because the strata only crop out at one place,and for the same reason a quarry on one side of a hill very often produces much better stone than on the other. Specimens of stone dressed up square, sent out by the quarrymen or agent, known as hand specimens, are very dangerous things to form an opinion on, because what looks very well in small pieces is really often of an inferior quality, and a stone that would appear coarse and rough in a specimen would not do so when in the mass. Stones that rub up to a smooth face are often not so durable as those of a rougher texture. To give an example, "best bed" Portland is much superior in color and texture to "brown bed" Portland, but far inferior to it in durability. Examine all the different beds in a quarry, noting the particular grain, texture, and color, of each bed; compare them with the buildings around, and if there be any old quarries near with the face exposed, see which of the beds stand out the most and show the old tool marks, and consequently have yielded to the action of the weather least. It frequently happens that the best stone in quarries is neglected, or only in part worked, from the cost of baring and removing those beds with which it may be associated and, in consequence,the inferior material is in such cases quarried, especially when a large supply is required in a short space of time, and at an insufficient price, which is often the case with respect to works undertaken by contract. As an economical supply of stone in particular localities would sometimes appear to depend on accidental circumstances, such as the cost of quarrying, the degree of facility in transport, and the prejudice that generally exists in favor of a material that has been long in use; and as the means of transport have of late years been greatly increased, it becomes essential to ascertain whether

better materials than those which have been employed in any given place may not be obtained from other, although distant localities, upon equally advantageous terms.

The relative facility with which good materials may be obtained in a district is, to a certain extent, marked by the appearance of the towns and villages in it, the comparative cost of obtaining them being in general better shown by the character of the ordinary houses than by that of the public buildings and large mansions, the stone for which may sometimes have been brought from comparatively considerable distances. From the frequent practice, however, of selecting those stones which yield readily to the tool, and are hence commonly termed freestones, whatever may be their mineralogical character, the most durable, and therefore eventually the cheapest, are far from being always employed. And it sometimes happens that we find the common cottages built of durable materials, while larger mansions and public buildings are not, the materials for the latter having been selected because they were soon readily worked up for ornamental parts, while those for the former may have been thrown aside in the same quarries because they yielded less freely to the tool.

In passing through the chief towns of Great Britain it will be easily seen, if more attention were paid to the mineralological character of the stone employed in the construction of the buildings, that frequent decay or decomposition, even in those erected within a few years, which we so often observe, would be avoided at comparatively small cost, and we should find fewer of our public edifices losing all traces of the finer work of the original structure. In estimating the relative durability of any given stone which may appear to resist decomposition from atmospheric influence in the country, no doubt due allowance should be made for the power of lichens to protect the external surface. These are not usually found in large towns, particularly those in which there is much coal smoke. We should not expect a sandstone, formed of quartz grains, loosely cemented by calcareous or argillaceous matter, to last so long when exposed to the weather, as one in which quartz grains were firmly bound together by a compact argillaceous or silicious substance. According to the texture and variable composition of the different calcareous and calciferous rocks, a judgment may be formed of their relative durability, and granites in which decomposition has already commenced in the felspar cannot be expected to remain firm under atmospheric influences.

The unequal state of preservation of many buildings, often produced by the varied quality of the stone employed in them, although it may have been taken from the same quarry, shows the propriety of a minute examination of the quarries themselves, in order to acquire a proper knowledge of the particular beds from whence the different varieties have been obtained. An inspection of quarries is also desirable for the purpose of ascertaining their power of supply, the probable extent of any given bed, and many other matters of practical importance.

An excellent and ready test when in the quarry, is to chip a number of small pieces off each bed or block, and carefully examine them under a small but powerful magnifying-glass. If the fracture is clean and sharp, and the grains are well cemented together, then it may be considered a durable stone; but, on the other hand, if the fracture has a powdery appearance, and the grains are ill-cemented, the stone is very likely to decay. Another test of a good stone, not alone applicable to limestones, is to soak a number of small pieces in diluted sulphuric acid for some days; its resistance to disintegration under this test shows its suitability or otherwise for building purposes in a large town, as well as where exposed to the salt rains and winds in situations near the sea.

In the construction of lines of railway and other large public works stone is frequently used which is obtained from the cuttings or excavations. Now the contractor, generally to save cost, blasts the stone, which is a most fatal mistake if durability is required. For although it may not be at first apparent, the blasting shakes the stone, and, before many winters are over, the stone begins to crumble to pieces. Of course, in the case of granite and other very hard stones, this remark does not apply, for having little or no stratification it cannot be quarried without blasting. If it is desired to put nothing but good stone into a structure, the material should be quarried and

weathered for some time before being used, as this serves not only as a check against the use of inferior stone, but prevents the unsightly greening after erection, which, for a time, so often disfigures a building, even if built of the most durable stone. At the Bath quarries some of the stone raised in the winter time is stacked in the workings and dried by coke fires in brasiers. Some stones, if wrought and put into a building green, with the quarry water in it, will go to pieces under the first frost, whilst the same stone, if seasoned under cover, will often stand well. In choosing a particular bed of stone in a quarry, it must be remembered that the lowest beds are not always the best. For instance, in the Portland series the hardest and most durable bed is on the top.

It is often desirable for stone to be tested by having a chemical analysis made, also by a hydraulic pressure for the crushing strength, as well as in a testing machine to obtain its tensile strength. In all these cases the specimens should be taken from various parts of the quarry, and from each bed, and certainly not less than six specimens should be selected from each to arrive at reliable results. We now come to the second division of my paper, on

### THE USE OF STONE.

Having found the quarry which produces stone of the quality you require, the next step is to specify the particular bed or beds which you desire to use. There is a great deal of looseness on this point in the practice of engineers and architects. Too often a stone of a particular district is specified without regard to the fact that, in the district named, stone of many different qualities is raised, some of which cost much more to work than others. This of course leads but to one result: the most profitable stone for the quarryman and mason is used, instead of the most durable. Another great evil is the outcry for large blocks, and the insisting that columns, figures, etc., should be cut out of one piece of stone. Many a good bed and quarry has been closed or rejected because it did not produce large blocks. Witness the case of the Mansfield Woodhouse quarries, where the stone was only used to a very small extent in the Houses of Parliament, because at that time blocks could not be got out large enough; but where it was used it has stood exceptionally well in contrast to the stone from Anston, which appears to have been selected principally because large blocks could be obtained.

In specifying the qualities and sorts of stone to be used in a structure, it should be remembered that in this climate decomposition sets in generally on the parts facing the S. S. W. and W., arising from the fact that the most prevalent storms of wind and rain are from those quarters. Lichens, which are a great protection to stone, unfortunately won't grow on structures in large towns, but they form an excellent shield to the stone in the country.

A great deal has yet to be learnt as to the proper use of the various and beautiful colors of different kinds of stone, and it is of more importance to have variation of color in a large town, because the fronts exposed to the wind and rain will always exhibit, more or less, the natural color of the stone, not being hid by lichens, as in the country. Some stone stands very well as ashlar or for plain mouldings, but if used for cornices, plinths, or in any part where damp or where the wet stands, so surely will it decay. It, therefore, is very necessary to specify one kind for the ordinary face work and a stone of superior durability for the portions exposed to wet and frost. However durable the stone may be, a good drip or weathering should be given to cornices or heavy projecting strings, as it enables the rain not only to run off, but at the same time to carry with it any dirt or dust that may have lodged on it, which, if left, grows moss and weeds, both very injurious to the durability of the stone. Fig. 1 is a very bad section of

FIG. 1.

base moulding, frequently used in early English work, for all the wet and dirt washed off the work above lodges in the sinking, and the frost gets in and attacks the stone at its weakest point—viz., the joints.

The use of metal cramps, iron particularly, is very objectionable; they nearly

always burst the stone after a time; slate dowels are the best. The stone parapet walls on the Thames Embankments are all built with slate dowels. Some of the masonry in the lower portions of Sir Christopher Wren's towers at Westminster Abbey are specimens of the evils of metal cramps. Bedding stone properly is a most important thing. It is a vicious plan to make the bed of columns or other masonry hollow, instead of true and square with the face; it invariably causes the stone to spall at the outside of the joint, as in the case of the Holborn Viaduct, besides causing the weight very often to be thrown on parts not intended to carry it, and a host of other evils, not to mention the unsightliness of walls and columns cracked in all directions. In masonry the joints should never, as a rule, be mitred, as is shown in

Fig. 2.

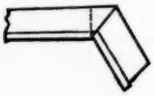

Fig. 3.

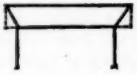

Fig. 2; or in lintels, as in Fig. 3, but as shown by the dotted lines. There is one exception to this rule, namely, in the case of a pointed arch which should be jointed

Fig. 4.

in the centre (Fig. 4); not with a keystone, as in a segmental arch. Where the stratum is thin, and the structure is exposed to heavy, driving rains, the outer courses of stone are often bedded at a slight angle outwards and downwards, as in Fig. 5, and the mortar is kept back an

Fig. 5.

inch or so from the face. This is done to keep the interior dry by preventing the rain from driving through the joints.

In designing rubble walls for buildings they should not be shown too thick, for if they are the masons are apt to build it with two faces, and to fill up the centre with loose rubble, often with little or no mortar. If exposed to vibration of any kind, they are very liable to burst. I have seen a great number of instances of this —one in particular, a church tower in the Lake district, which was cracked from top to bottom and all round—in fact, bursting under the vibration caused by ringing the bells, and the superincumbent weight of the spire.

In walling, masons always like to put the best face of a stone outwards, and the result is, you get large spaces which are filled up with mortar and spalls; few workmen can resist the temptation to put a long stone parallel with the face of the work, instead of endways. The want of bond stones is the great defect of walling generally. A good plan where the stone runs small is to build three or more courses of brickwork right through at certain levels to act as a tie. With stone from most geological formations, it is of great importance that it be placed bedwise, or as it lay in the quarry. This, if not properly attended to, leads rapidly to general decay. There are various methods of finding the beds of stone—for instance, rains always run from top to bottom, or with a downward direction. Shells or fragments of shells lie flat as they would on the sea-shore. In most sandstones the streaks or layers exhibit the bed very plainly.

In conglomerates, the pebbles, like the shells, are generally lying on the flat side. Added to all these, it is generally usual for the quarryman, before sending the block away, to mark on it which is the bed. The bed is therefore not so hard to find as some try to show, and a little careful examination of the peculiarities of the particular stone you are using will make you to detect at once if the stone is on its bed or not. After a structure is erected, or, as in the Scotch method, during construction, it is usual, if the work is of any moment, to clean it down; too much attention cannot be paid to seeing that all the mortar and slush is thoroughly washed off, for if it be not, the frost and rain will bring it off, and it gathers on the projections and under the mouldings, causing them to decay. It is a common practice, when a stone gets dirty or discolored, or is decaying, to cut or drag off the surface of the stone. This should never be done, for if the stone is dirty it can be rubbed

and washed to get it clean. Stone throws out, as it were, a hard skin for its protection when first exposed, and if that skin be taken away the protection is gone, and it is very liable to decay. If the stone is really decaying, any number of new faces won't stop it. In the construction of works where much stone is used, it is very important to have clerks of works and inspectors who have served as masons. In the greater number of cases it will be found that in early life most of the clerks of works, inspectors, and foremen have been carpenters or joiners. Too often you find masons knowing nothing beyond their trade, while carpenters and joiners are a better informed and superior class of workmen. A great deal of the inferior stone that is used, and the bad bedding that is permitted, is due, I think, to the fact that the workmen know that their masters are not masons. I am not finding fault with the men who by their industry have raised themselves from journeymen to positions of trust. Far from it, it is most creditable to them; but on the other hand, it is equally discreditable to the masons that they allow the journeymen from another trade to take posts of trust which they might fill with greater advantage, where stone is much used, if they were steady and educated themselves for it.

Although I must now come to a close, do not think the subject is exhausted. I could say a great deal more on this important material; but as I hope there will be a valuable discussion afterwards from the members and gentlemen present, some of whom are connected with quarries, I shall defer any further observations to a future time. In some parts of my paper I have made extracts from Sir Charles Lyell's and Sir H. De la Beche's valuable works, from blue-books, and other publications which I have consulted. To those familiar with works treating on stone (I am sorry to say, very limited in number), these extracts will be at once apparent. In conclusion, if engineers and architects really desire durability, they must be prepared to pay a reasonable price, both for the raw material and the workmanship on it; and they will, I think, find that they will be heartily seconded in their endeavors, both by the quarryman and mason, in the selection of the best stone; and in the long run it will prove not only one of the best of building materials, but the cheapest.

## SOLAR HEAT—ITS INFLUENCE ON THE EARTH'S ROTARY VELOCITY.

By CAPTAIN JOHN ERICSSON.

(*Continued from page* 14.)

The unpublished tables containing the rivers flowing towards the poles, referred to in the preceding article, furnish elements relating to the latitude of and weight transferred by 102 rivers, 24 of which discharge directly into the Arctic Ocean, draining 5,351,000 sq. miles of basin. The remaining 78 rivers drain 7,833,000 sq. miles; hence an area of 13,184,000 sq. miles comprises the entire river system of both hemispheres conveying water towards the *poles*. It is a noteworthy circumstance that nearly an equal extent of area is drained by the rivers flowing towards the *equator*, viz., 13,246,000 sq. miles. (See the Tables published in a preceding article.)

The mean latitude of outlet of the 24 rivers which discharge directly into the Arctic Ocean, is 69 deg. 15 min.; that of the centre of their basins is 60 deg. 3 min. Now the velocity round the earth's axis of rotation in parallel 69 deg. 15 min. being 538 16 ft. per second, while that of parallel 60 deg. 3 min. is 758.22 ft. per second, it will be seen that the mean rotary velocity of the water during its course from the centre of the basins to the points where it enters the polar sea, is diminished 220.06 ft. per second. The unpublished tables before referred to, show that this diminution of rotary velocity of the waters conveyed by the Arctic rivers, imparts a mechanical energy of 91,111,578,300 foot-pounds per second to the earth (a computation, it should be observed, based on the assumption that the precipitation on the basins of the 24 Arctic rivers varies, ac-

cording to latitude, from 20 in. to 11 in. in 12 months). The water of the remaining 78 rivers flowing towards the poles—including river La Plata, but excluding the Nile—imparts, as shown by the tables, a rotary energy of only 20,399,766,300 foot-pounds per second. It will be found, on examination, that the outlets of the rivers imparting this small *compensating* energy are removed so far from the tropics, and hence from the direct influence of a vertical sun, that the water which they discharge cannot be converted into vapor until it has reached, in its course towards the equator, a position much further from the poles than the centre of the respective river basins. La Plata might possibly be deemed an exception, but several of the other 77 rivers under consideration transfer their waters, as stated, to positions much nearer the equator than the centre of their basins, before complete evaporation takes place. We shall, therefore, overestimate the compensating energy exerted by these rivers, if we assume that their water in its course through the ocean towards the equator, becomes evaporated by the time it crosses the parallels corresponding with the centre of the basins from whence the motion proceeds. Consequently the compensating force of 20,399,766,300 foot-pounds per second, will be wholly neutralized by the retarding energy called forth during the stated return movement of the water. Indeed a critical examination of the subject could not fail to show that some *retardation* actually takes place. The amount, however, is too small to affect materially the general question of retardation of the earth's rotary velocity, and therefore may be neglected. But the compensating energy of the water of the 24 rivers discharging into the Arctic Ocean, is so far inferior to the *retarding* energy called forth during the retrograde motion towards the tropical seas, that the earth's axial rotation suffers an amount of retardation which, as already shown, considerably exceeds that of all the rivers flowing in the direction of the equator.

The following additional explanation will more fully elucidate the subject. It was shown in a preceding article that the water discharged into the cold polar sea, in place of being there converted into vapor, at once commences a retrograde motion towards the tropical seas; and that owing to this retrograde motion and the consequent retreat of the circulating water from the axis of rotation, the whole of the compensating energy imparted to the earth will be neutralized by the time a parallel is reached which corresponds with the mean latitude—60 deg. 3 min.—of the centres of the respective river basins. Now the rotary velocity of that parallel is 758.22 ft. per second, while the mean rotary velocity of outlet into the Artic Ocean is 538.16 ft. per second; hence 758.22—538.16=220.06 ft. per second, *increase* of velocity round the axis of rotation takes place during the transfer of the water from the outlet of the rivers in the polar sea, to the parallel referred to. The diminution of rotary velocity of the water in its course to the Arctic Ocean and the subsequent *increase* of rotary velocity being alike, it will be evident, without referring to previous demonstrations, that when the retrograde current arrives at lat. 60 deg. 3 min. the entire *compensating* energy has become neutralized. It will be evident also that when the retrograde motion reaches parallel 49 deg. 54 min., the rotary velocity of which is 220.06 ft. per sec. greater than that of the centre of the river basins, a *retarding* energy has been called forth of equal amount with the neutralized compensating energy of 91,-111,578,300 foot-pounds per sec.

It results from the magnitude of the earth's present vis viva and the laws of motion referred to in the preceding article, that the retardation of one second in a century demands a continuous expenditure of mechanical energy of 37,909,059,-765 foot-pounds per second. Hence the loss of 91,111,578,300 foot-pounds of vis viva per sec., which the earth suffers by the counteracting influence of the water circulating between the Arctic Ocean and the tropical seas, in the manner explained, will cause a retardation of 2.40342 secs. in a century. Adding the retardation of 1.42071 sec. previously established, it will be found that the river systems of both hemispheres call forth an amount of retarding energy capable of changing the length of a century 3.82413 secs. We have thus accounted for nearly one-third of the amount of retardation of the earth's rotary velocity which modern astronomy has deduced fram the apparent acceleration of the moon's mean motion. No reasonable objection can be urged against

our conclusions with reference to the return-currents, as it may be satisfactorily demonstrated that the water discharging into the Arctic Ocean by the Northern rivers, is not, during its return movement towards the equator, converted into vapor until it has reached a parallel much nearer the tropical seas than the one assumed in the foregoing calculations.

The investigation of the river systems of both hemispheres, and the ocean currents connected with the same, being thus concluded, the chief cause of the retardation of the earth's rotary velocity now claims our attention, viz.: the retarding influence called forth by the movement of the water of the oceans in the temperate zones, in the direction of the equator, to make good the loss produced by evaporation within the tropics.

It will be indispensable, before examining the result of this movement, that we clearly comprehend that, although the sea is composed of particles unconnected with the body of the earth, free to move in all directions in conformity with the laws of equilibrium, yet, owing to the small depth compared with the earth's diameter—proportionably not more than a sheet of cartridge paper bent round an ordinary terrestrial globe—and, owing to the varying depth of the ocean and the intervening continents and islands, the water of the sea is urged round the axis of rotation as effectually as the solid matter composing the body of the earth. Accordingly, water which moves from the temperate zones towards the equator through the sea retards the rotary velocity of the earth with as much energy as water confined in river beds moving in the same direction. The experiments with the dynamic register prove conclusively, that a given weight of vapor transferred in a given time from the equator in the direction of the poles cannot restore the retarding energy produced by an equal weight of water transferred in equal times towards the equator. Consequently if the whole quantity of water precipitated on the seas of the temperate zones is not evaporated within the parallels in which the precipitation takes place, a corresponding portion of the water thus precipitated must return to the parallels in which the evaporation was originally effected. Evidently, then, the main point of our inquiry is confined to the question, what proportion of the water precipitated on the seas in the temperate zones is not there again evaporated? It needs no demonstration to show that the quantity not evaporated must return to the tropical waters. In the absence of trustworthy experiments enabling us to determine the amount of evaporation and precipitation at sea, we must judge by what we find on extensive planes free from mountains and nearly on a level with the ocean. The Mississippi river basin probably furnishes a better comparison for the purpose than any other level plane of equal extent. It may be objected that the amount of evaporation on land is different from that at sea—a reasonable objection—but the difference will unquestionably be in favor of assuming considerable return currents towards the tropics, since the heated soil of river basins, and the increase of evaporating surface resulting from the numerous minute projections on the ground produce a more rapid evaporation than on the ocean. Regarding the amount of precipitation, it should be observed that the previously published tables are based on an annual average for the whole of the Mississippi basin of only 30 in. Considering that the rain gauges of the lower portion of this basin, which is nearly level with the Gulf of Mexico, indicate 60 in. for 12 months, it would be inconsistent to suppose that the amount of ocean precipitation between the tropic of Cancer and latitude 42 deg., a zone the mean latitude of which corresponds with the lower Mississippi valley, is less than the average of the basin of that river, viz., 30 in. Nor would it be consistent, as we have shown, to suppose that a greater proportion of the water precipitated is re-evaporated at sea than upon this basin, namely, 22.5 in., or 0.75 of the average rainfall of 30 in. per annum. Consequently we may, without fear of committing any material error, assume that the precipitation and re-evaporation on the oceanic zone between the tropics and the latitudes 42 deg. north and 42 deg. south, are the same as the mean observed on the entire Mississippi basin, viz., 30 in. precipitation and 22.5 evaporation. Accordingly the depth of water not re-evaporated, and, therefore, returned to the seas within the tropics, will be 7.5 in.

On this basis the accompanying Table has been constructed, and the retarding energy computed. The reason for select-

ing latitude 42 deg. as the mean limit of return currents resulting from precipitation is that, in the northern hemisphere, the seas extend but little beyond this latitude (fully three-fourths of the surface of the earth between latitude 42 deg. and the Arctic Ocean, consisting of land), while in the southern hemisphere, we have good grounds for assuming that beyond the 42d parallel, the precipitation and evaporation are nearly balanced. Regarding the accompanying Table, it will suffice to state that the increase of rotary velocity, 115.44 ft. per sec., has been determined by comparing the mean latitude of the oceanic zones referred to, and the tropical latitude 23½ deg.; the rotary velocity of the former being 1277.48 ft., and that of the latter 1392.92 ft. per sec. A rate of 115.44 ft. per sec. is generated by a fall of 208.22 ft.; hence if we multiply this fall by the weight of water transferred to the tropics, we establish the fact that the total retarding energy amounts to 263,343,000,000 foot-pounds per sec. This computation, it will be observed, is based on the assumption that the retarding influence called forth by the return movement produced by precipitation in the temperate zones, ceases when this movement reaches the tropical zone. It is true that the motion of a certain portion of the returning water will extend to the equator, to fill the void already referred to, and before complete evaporation is effected; but, on the other hand, considerable evaporation takes place previously to reaching the tropics. Besides some allowance, though small, should be made for the tangential force imparted to the earth, from west to east, by the vaporous polar current. Again, the last 5 deg. before the returning water reaches the equator, produces scarcely any increase of rotary velocity, and hence no material counteracting energy. Accordingly, the result of our calculations recorded in this Table, cannot be far from correct.

*Table of Oceans and Land between Latitudes 42° North and 42° South.*

| Oceans between the tropics and latitudes 42° north and 42° south. | Area in square statute miles. | Water transferred to the tropics. | | Rotary velocity. | Increase of rotary velocity. | Retardation. | Oceans and land within the tropics. | Area in square statute miles. |
|---|---|---|---|---|---|---|---|---|
| | | Cubic feet per second. | Pounds per second. | | | | | |
| North Pacific Ocean | 8,697,000 | 4,794,400 | 2,996×10⁵ | Feet per second. 1277.48 | Feet per second. 115.44 | Foot-pounds per second. 62,392×10⁵ | Land from equator to tropic of Cancer | 9,982,900 |
| North Atlantic " | 5,406,000 | 2,980,140 | 1,862×10⁵ | " | " | 38,782×10⁵ | Water from equator to tropic of Cancer | 29,156,000 |
| South Pacific " | 9,962,000 | 5,491,690 | 3,432×10⁵ | " | " | 71,468×10⁵ | Land from equator to tropic of Capricorn | 8,560,000 |
| South Atlantic " | 5,256,000 | 2,897,440 | 1,810×10⁵ | " | " | 37,707×10⁵ | Water from equator to tropic of Capricorn | 30,230,000 |
| Indian " | 7,387,000 | 4,072,190 | 2,545×10⁵ | " | " | 52,994×10⁵ | | |
| Total | 36,708,000 | 20,235,860 | 12,645×10⁵ | " | " | 263,343×10⁵ | Total area of tropics | 77,928,900 |

We have now to consider the loss of mechanical energy resulting from the loss of heat generated by friction among the particles of the opposite currents of atmospheric air circulating between the equator and the poles. Unless some powerful process of compensation can be shown to exist, an additional source of retardation of the earth's rotary velocity resulting from solar heat, will be established. The practical mind at once rejects the prevailing notion that there is a perfect exchange of motion without loss of energy between the heated equatorial currents directed towards the poles and the returning cold currents directed towards

the equator. We have already pointed out the fallacy of the deductions of Laplace, attributable to his ignorance of the convertibility of mechanical and molecular motion. Our highest modern authority, likewise, ignores the loss of mechanical energy resulting from the generation of heat by contact and friction between opposite currents of air. Sir John Herschel (see "Outlines of Astronomy," page 153) says: "The constant friction produced between the earth and the atmosphere in the regions near the equator must (it may be objected) by degrees reduce, and at length destroy, the rotation of the whole mass. The laws of dynamics, however, render such a consequence generally impossible; and it is easy to see, in the present case, where and how the compensation takes place. The heated equatorial air, while it rises and flows over towards the poles, carries with it the rotary velocity due to its equatorial situation into a higher latitude, where the earth's surface has less motion. Hence, it will *gain* continually more and more on the surface of the earth in its diurnal motion, and assume constantly more and more a *westerly* relative direction; and when at length it returns to the surface, in its circulation, which it must do more or less in all the intervals between the tropics and the poles, it will act on it by its friction as a powerful south-west wind in the northern hemisphere, and a north-west wind in the southern, and restore to it the impulse taken up from it at the equator." We have already demonstrated that currents of air cannot augment the velocity of rotating bodies, and that rotating bodies cannot produce currents of air or augment their speed, without great loss of mechanical energy—owing to the fact established by the dynamic register, that a considerable portion of the motive energy is converted into heat. Consequently the augmentation of the rotary velocity of the particles of air composing the polar current, will be attended with great loss of mechanical energy during their course to the equator. It would be an insult to the intelligence of well-informed engineers to suppose that they need proof of the obvious fact, that, when the polar current reaches the equator, its rotary velocity is not so great as that of the circumference of the earth unless some other force than that communicated by contact with the earth's surface restores the lost energy and flagging velocity. It is susceptible of practical demonstration that so considerable is the loss of mechanical energy caused by the conflicting motions of the opposite atmospheric currents circulating to, and from, the poles, that, in the absence of some adequate force to restore the lost motion, the body of air returned from the poles would lag far behind the earth's rotary velocity at the equator, and that consequently a continuous easterly current, amounting to a tempest, would prevail in the tropical regions. By what means, then, is the force supplied which imparts fresh rotary energy to the returning polar current, and thereby prevents a perpetual easterly wind of destructive violence within and near the tropics? The average calorific energy of solar radiation within 30 deg. of each side of the ecliptic, is capable of evaporating fully 2 lbs. of water daily upon 1 sq. ft. of surface, or 25,000 tons on a square mile, during each diurnal revolution. Consequently the polar current in its progress towards the equator will be pierced by an ascending column of aqueous particles possessing the same rotary velocity as the surface of the tropical seas. The result is self-evident; the particles of air composing the polar current will gradually acquire, by contact during the onward movement, a rotary velocity equal with that possessed by the aqueous particles of the ascending column. The adequacy of the latter to impart the necessary rotary velocity cannot be questioned in view of the enormous weight, 25,000 tons per sq. mile, raised daily by evaporation. The observed prevalence of westerly winds (absurdly attributed to the action of "some force external to the earth") is readily explained if we consider the vast amount of rotary vis viva imparted to the atmosphere by the tropical vapors during their course towards the poles. Indeed, the force thus imparted from west to east is so great that, but for the loss of energy caused by the conflicting motions of the currents between the equator and the poles, a strong westerly wind would prevail in the temperate zones.

Having thus briefly examined the means by which the loss of mechanical energy resulting from the conflicting motions of the equatorial and polar currents is made good, and shown how the excess of rotary velocity of the tropical

vapors is utilized, we may now enter on the task of summing up the amount of counteracting force, and determining the consequent total amount of retardation of the earth's rotary velocity. The retarding energy exerted by the 78 rivers flowing towards the poles which do not discharge directly into the Arctic Ocean being 20,399,766,300 ft.-lbs. per second, while the water returned from the seas of the temperate zones to the tropical waters, as shown by the preceding Table, exerts a retarding energy of 263,343,000,000 ft.-lbs., it will be seen that the total counteracting force is 283,742,766,300 ft.-lbs. per second. Multiplying this sum by the number of seconds in a century, we determine the retarding force exerted in that time; and by deducting the product from the earth's vis viva, we obtain the necessary data for computing the retardation. Bearing in mind that the velocities are as the square root of the forces, we are thus enabled to determine that the retardation amounts to 7.48482 secs. in a century. The counteracting energy exerted by the *sediment* transferred by the southern rivers, has not been included in this calculation, on the ground that the solid matter carried in an opposite direction by the polar rivers, calls forth an amount of propelling energy fully balancing the counteracting force. As already demonstrated, the retardation produced by the river systems of both hemispheres, and the return currents connected with the rivers flowing towards the poles, amounts to 3.82308 secs. in a century. Adding this to the before-mentioned retardation of 7.48482 secs. we establish the fact that the evaporation caused by solar radiation, within and near the tropics, calls forth a counteracting energy, which retards the earth's rotary velocity11.3079 secs. in a century. Future researches will show that this amount is greatly underestimated. I maintain that solar influence subjects the earth to an amount of retardation many times greater than that inferred from the observed discrepancy between the mean angular motion of the moon and the earth's rotation. Careful examination of the foregoing calculations cannot fail to convince the competent that the retarding energies have all been greatly underrated. Again, the disturbing influence of the matter transferred to fresh localities on the earth's surface has been determined by calculating the mechanical energy abstracted during the increase, and imparted during the diminution of velocity round the axis of rotation. Evidently if we base the computations on the difference of the rotary vis viva possessed before and after the transfer a higher result is reached.

It will be objected that the earth's retardation cannot exceed the amount indicated by the apparent acceleration of the moon's mean motion. This objection would be unanswerable if the assumption were true that the moon moves in a non-resisting medium; but the emission theory of heat and light being untenable, we are compelled to admit that the ether is a vehicle capable of transmitting mechanical energy, hence amenable to certain mechanical laws. The solar calorimeter has proved that a sunbeam of one square foot section exerts a mechanical energy of 4690 foot-pounds per minute at the boundary of our atmosphere. Can we question that a medium capable of transmitting an amount of mechanical energy sufficient to raise a ton 2 ft. high in one minute, by a wave of only one square foot of section, shares with gross matter the properties of inertia and friction? It must be admitted, therefore, that the moon encounters resistance during its angular motion round the earth. Of course the diurnal rotation of the latter is likewise retarded, but the retardation is of a very different nature from that affecting the moon. The earth simply *rotates in the ether* (its orbital motion has nothing to do with the present question), the moon *moves through it.* Obviously the magnitude of the retarding energies will depend on the following elements: Extent of convex area presented by each of the two spheres, the mean rotary velocity of the earth's surface, angular velocity of the moon, rotary vis viva of the earth, and lastly, the moon's orbital vis viva. Demonstrations and calculations founded on these elements show positively that the moon's angular motion suffers a greater amount of retardation relatively, than the rotary motion of the earth. Hence, if the earth's rotation were not subjected to retarding influences within itself, the moon would lag behind. Its mean motion, instead of being apparently accelerated, would be actually retarded.

# CONCRETE.

From "The Mechanics' Magazine.

The use of concrete is becoming more and more general every day, both in large engineering works and in house building, yet there is nevertheless probably more misconception about it than any other material used in construction. The points of most interest about it are,—the best materials for it, the proper proportion of lime or cement, its strength, and especially the *questio vexata*—the loss of bulk in mixing. We propose to say a few words on each of these points.

Three ingredients are absolutely necessary to form a good, sound, strong, and economical concrete, viz.: A hard, incombustible, and imperishable substance to form bulk; a finer material to fill up the interstices; and a cement or lime to unite the whole. The most suitable materials for the first ingredient are clean gravel, shingle, flints, stone chippings, broken pottery, clinkers, slag, brick bats, burnt clay, etc. It is, however, very important that the gravel should be clean and quite free from loam and dirt, otherwise it must be carefully washed and sifted. There is a great deal of misapprehension as to the proper size for the gravel, to give the best results. Some engineers and architects specify that no piece shall be larger than a pigeon's egg, others that no piece shall be used that will not pass through a 1½ in. ring. The general idea seems to be that larger pieces injure the strength and quality of the concrete. This is a mistake—a lump of stone in the concrete is certainly stronger than it would be if it were broken up and cemented together again. The real objection to it is that if a barrowful of large stones is tipped altogether in a heap the interstices never get properly filled in with the ordinary shingle or gravel, and consequently large hollow spaces are left or are else filled in with sand and cement to the detriment of the quality of the adjoining concrete. A proper admixture of larger pieces, *if judiciously added*, actually increases the quality of the concrete, as there are fewer interstices to be filled with a given quantity of cement and sand. The larger lumps should be distributed; but this need not involve extra labor, as it is not necessary for the distribution to be uniform, it being only important to prevent the large lumps from being in contact with each other so as to form large hollow crevices. There can be no objection to a piece of stone weighing 56 lbs. and upwards being used, provided it is entirely surrounded by ordinary gravel and not adjacent to other pieces of a similar size. It might possibly be injudicious to use any lumps larger in diameter than half the thickness of the wall being built, and even these should be used sparingly. We are not advocating the use of large pieces of stone indiscriminately or in great quantities, but we maintain that a judicious admixture of them, instead of being injurious, is actually an improvement and ought to be encouraged. The strength of concrete depends more on the comparative quantity of cement compared with the cubic contents of the spaces between the stones, than as compared with the absolute bulk of all the ingredients. For this very reason *isolated* lumps improve the concrete by reducing the percentage of cavities—and for the same reason too large a quantity of lumps close together, depreciate the quality of the concrete by increasing the cavities.

In practice, the sand and lime (or cement) ought, *when mixed*, to be a little in excess of the quantity actually required to fill up all the interstices properly. If less is used, the concrete is not sufficiently cemented together; if more, it is not so economical as it might be. Lime and sand, and cement and sand, lose about one-third of their bulk when made into mortar, therefore the sand alone, before mixing, should be slightly in excess of the spaces to be filled.

The spaces between the stones in ordinary clean gravel or shingle have been found by experiment to vary from 32 to 37 per cent. of the gross bulk of the gravel; that is to say, it would require that quantity of water to fill up the interstices. It is, however, evident that it would be impossible to get in an equal quantity of any solid, such as sand, as it could not penetrate into every crevice absolutely to the points of contact between the stones, as water does. By a series of carefully conducted experiments, it has

been ascertained that the average quantity of sand that can be mixed with clean shingle without increasing the bulk, and therefore exactly filling the crevices as far as practicable, is 12 per cent. Any additional sand beyond this quantity increases the gross bulk of the mixed sand and shingle by the same amount. But when the same experiment was repeated with 40 parts of sand and 20 parts of blue lias lime, all mixed together with 100 parts shingle and wetted, the total bulk was only 125½. Now we know from previous experiments that when sand and blue lias lime are made into mortar in the above proportion, the resulting mortar is only .714 of the combined bulk of the original lime and sand; consequently 40 sand and 20 lias lime ought to produce 42¾ measures of mortar; but the total bulk was only increased 25½, therefore the remainder or 17¼ mortar must have found its way into the cavities of 100 parts of shingle. But as the bulk of the mortar was about the same as the sand it was made from, in this instance about 17 per cent. of sand must have gone into the interstices, or just about half the cubical contents of the spaces as ascertained by the quantity of water they will contain. We have no doubt that a greater quantity of sand could always be worked in, when mixed with lime and water and beaten up in the state of mortar, than in its natural state.

Experiments would therefore seem to indicate that one volume of sand is sufficient for five volumes of gravel, but in practice one of sand to four of gravel would be a better proportion, as the spaces would be in excess of the above results if the concrete were not properly rammed, and it is better to have too much sand than too little, as a deficiency affects the strength, while an excess only adds to the expense. We remember having seen cement concrete specified to be composed of 3 gravel, 2 sand, and 1 cement; but we fancy 4 gravel, 1 sand, and 1 cement, would give far better results, as the cement mortar in the latter case would have been half cement and half sand, and would therefore have had three-fourths of the strength of neat cement; whereas cement mixed with 2 parts sand has only half the strength of the neat cement, and with 3 parts sand only one third of the strength. The above relative strengths of cement and cement-mortar are not assumed, but have been generalized from a great number of experiments made on the tenacity of cement and sand mixed in various proportions. It is important that the sand should be clean and sharp; recent experiments indicate that the use of loamy sand reduces the strength of the cement-mortar by about ⅓.

The quantity of water required in mixing a yard of concrete varies from 25 to 39 gals., according to the quantity of cement and sand used, the larger quantity being required when the concrete is made very strong, such as 5 of gravel and sand to 1 of cement. About 5 gals. of the above are used up in moistening the surface of all the stones. Concrete ought to be turned over 3 or 4 times in mixing, and as little water used as is practicable. If it looks wet enough after it has been turned over once, too much water has been used, for it generally looks wetter each time it is turned, although no additional water is used. The concrete, when mixed, should be thrown into its final position from a height of 7 or 8 ft., or what is better still, well rammed after it is in position. This forces the gravel stones closer together, reduces the total bulk of the interstices, and brings the semi-fluid mortar to the surface, showing that all the cavities are properly filled.

Medina cement is inferior to Portland for concrete, possessing only about ⅓ the tenacity. It is useful to form a thin coating of quick setting marine concrete, the bulk of which has been made with Portland cement. It hardens rapidly, and prevents the rising tide from washing the slower setting Portland out, before it has had time to harden sufficiently to resist the action of water in motion.

The quantity of lime or cement usually used in concrete varies from a 5th to a 10th of the bulk of the other material. A 5th is strong enough for any purpose if carefully and properly made, while less than a 10th can scarcely be relied on. In foundations where the concrete is of great depth, and has to bear a very large super-incumbent weight, the lime probably ought to be as much as a 5th, but a 6th would generallly do for ordinary foundations, while a 7th is quite sufficient for backing to arches and retaining walls. In building dwelling-houses, warehouses, chapels, etc., the

concrete is made of Portland cement, and should not be less than 1 of cement to 7 of material, but good boundary walls have been made with 1 of cement to 9½ material.

Before concluding we will say a few words on the disputed question of the loss of bulk that the materials undergo when mixed into concrete. Experiments have repeatedly been made to ascertain the extent of the loss, if any; but the results are by no means satisfactory, as some seem to show that only the lime is lost, while others show a loss of ¼ of the ballast in addition to the lime. But the experimenters only tell us how much lime was used to a certain quantity of what is vaguely described as ballast, without saying what proportion of sand there was in the ballast, and this will probably account for the discrepancies. The following experiments, never before published, were made recently while a quantity of concrete work was being carried out in some sea defences on the South Coast. The shingle used was perfectly clean and free from sand, and the sand was all sifted.

*Experiment I.*

| | | |
|---|---|---|
| Clean shingle..... | 62½ | |
| Clean sifted sand.. | 25 | |
| Total ballast... | 87½ | made 78½ concrete. |
| Blue lias lime. | 12½ | |
| | 100 | |

In this instance, the sand being in excess, a portion of it equal to the cavities was absorbed, while the excess increased the bulk of the concrete. Here 87½ parts of ballast made 78½ parts concrete, the loss being 9 in 87½, or 10⅓ per cent. Had the sand been only 17 per cent. of the quantity of shingle it would all have been absorbed in the interstices, and the quantity of concrete would have been about equal to the original quantity of shingle: —thus 100 shingle and 17 sand would have made (with a proper quantity of lime) 100 concrete, and the loss would have been 17 in 117, or 14½ per cent. This latter is an extreme case, and shows the maximum loss of bulk in the sand and gravel, in addition to the lime disappearing, that can occur in freshly mixed concrete. A further settlement of about 4 per cent. would probably take place during the setting, making a total maximum loss of bulk equal to 18½ per cent. in extreme cases.

*Experiment II.*

| | | |
|---|---|---|
| Clean shingle... | 68¾ | |
| Clean sifted sand | 27¼ | mixed = 87½ |
| | 95½ | |
| Blue lias lime..... | 12½ | made 89¼ concrete. |
| | 100 | |

(which were in the same relative proportion as in Experiment I., viz., 5 shingle to 2 of sand).

In this second experiment the shingle and sand were first thoroughly mixed without any lime; the loss in bulk by the sand occupying the interstices was equal to about 12 per cent. of the gross bulk of the shingle alone, as referred to in the commencement of this article. The sand now filled the interstices and the lime was added; the concrete in this instance was about 2 per cent. in excess of the bulk of the mixed sand and gravel when *first mixed*; but after setting, the bulk would be about 4 or 5 per cent. less, *i. e.*, about 3 per cent. less than the bulk of the sand and gravel *measured when mixed together* without any lime, or 12 per cent less than the original bulk of the sand and gravel *before mixing*.

The loss of bulk therefore of the shingle and sand seems to vary in extreme cases from 18½ to 3 per cent., according to whether the shingle is entirely clean and free from sand, or whether the interstices are filled with sand, and also as to whether the sand is less, equal to, or more than the interstices in the gravel or shingle.

This clearly shows that the loss of bulk can be accounted for theoretically without any mystery. There is no contraction of the solid gravel stones, and the concrete is never less than the clean gravel, although always less than the gravel and sand combined, *vaguely* called ballast in most experiments. The loss of bulk is due, first, to the loss of bulk in the sand and lime or cement, when mixed into mortar; secondly, to the quantity of mortar in the interstices of the gravel; and thirdly, to a settlement in setting. We have before said that sand and lime in the proportion of 2 to 1 make .714 of their united bulk of mortar; if the proportion is 3 to 1 the mortar only amounts to .63; with cement in any proportion from 1 to 1 to 3 to 1, the resulting cement mortar is

just $\frac{2}{3}$ of the original bulk. If then we know the proportion of gravel, sand, and lime, or cement, we can ascertain the quantity of concrete that can be made from them approximately, as follows, viz.:

Add $\frac{2}{3}$ of the lime and sand to $\frac{5}{6}$ of the gravel, and reduce the total about 4 per cent. for settlement.

We should not have dwelt so much at length on the above particulars, but as the use of concrete is extending, its characteristics ought to be understood.

## SELENITIC MORTAR.

From "Engineering."

For some months past a series of careful and exhaustive experiments have been in progress at South Kensington, in order to test the value of a new kind of cement and mortar. This substance is the invention of Colonel Scott, R. E., and was referred to by us in our notice of the International Exhibition buildings on the 23d December last, as having been used in the construction of the French annexe. It has been named by Colonel Scott, selenitic mortar, and the process of production consists in mixing with the water used in the preparation of the mortar, a small quantity of sulphate of lime, in the form of either plaster-of-paris, gypsum, or green vitriol. These substances having been intimately mixed, the lime is added and ground with the water or sulphate into a creamy paste. The mixture is prepared in the pan of an ordinary mortar mill, in which the water and sulphate are first introduced, and subsequently the lime. After the lime has been ground for 3 or 4 minutes, the sand, burnt clay, or other ingredients are added, and the whole is ground for 10 minutes. By this invention, ordinary lime can be at once converted into a species of cement mortar which sets rapidly and well, and can be used for concrete, bricklayer's work, or stuff for plastering, at a cheaper rate than that made from lime in the ordinary way. From his experiments, Colonel Scott finds the use of sulphuric acid to give the best results, so that this substance is used in preference to plaster-of-paris or gypsum, although the latter materials will answer for all practical purposes. Sufficient acid is contained in plaster-of-paris to effect the necessary chemical change, and to prevent the lime from slaking, which in effect is the secret of the whole process. The lime, by this means, is enabled to take twice as much sand as when slaked, its fiery nature being brought under control. Any lime can be made selenitic by Colonel Scott's process, and the more hydraulic it is, the better are the results obtained with it.

The invention is not only applicable to cement manufacture and mortar mixing, but its use extends to brick making. A number of bricks have been made since the opening of the Exhibition, by Mr. Large's dry brick press in the pottery machinery annexe. These bricks are composed of 1 part lime to 8 or 10 parts sand or burnt clay, and they are found to be ready for use in about 10 days after pressing without being burned. It is found that these bricks do not swell as is ordinarily the case from the slacking tendency of lime when not made selenitic. The proportions adopted for various purposes are as follows: Mortar for bricklaying, water half a pail, plaster-of-paris, 4 lbs.; mix and add in the pan of the edge-runner 2 or 3 pails of water, a bushel of lime, and 6 bushels of sand; grind for 10 minutes. For mortar for pointing, water, plaster, and lime as before, and add 2 parts chalk, slaked lime or whiting, and 2 parts sand. For coarse stuff for plastering, same ingredients as for mortar, but coarser sand, and grind for five minutes only. For fine stuff for plastering, water, plaster, and lime as before, a bushel and a half of chalk and 2 bushels of fine mashed sand. For coarse stuff on lath add with the lime 5 lbs. of hair, which need not be previously beaten. For rough stucco, same as for mortar, but 4 bushels only of sand. Plastering on walls can be done by this process as 2-coat work, while ceilings can be floated immediately after the application of the first coat and set in 48 hours.

An examination of the walls of the

French annexe and some recent samples of work in the experimental yard at South Kensington, have shown us the thorough adaptability of this material to the various purposes to which we have referred. The cements are very quick setting, and they produce a very hard and finely finished surface.

| Nature of Experiment. | Age of joint or sample in days. | Composition of Mortar in parts. | | Breaking weight of joint or sample. |
|---|---|---|---|---|
| | days. | | sand. | lbs. |
| Two bricks joined crosswise with selenitic mortar, giving an area of 20 square inches of joint..... | 14 | 1 Medway gray lime.. | 3 | 255 |
| Ditto ditto ditto ..... | 14 | 1 " " .. | 4 | 327 |
| Ditto ditto ditto ..... | 14 | 1 " " .. | 5 | 340 |
| Ditto ditto ditto ..... | 14 | 1 " " .. | 6 | 339 |
| Ditto ditto ditto ..... | 14 | 1 Lias lime ..... | 3 | 259 |
| Ditto ditto ditto ..... | 14 | 1 " ..... | 4 | 144 |
| Ditto ditto ditto ..... | 14 | 1 " ..... | 5 | 160.5 |
| Ditto ditto ditto ..... | 14 | 1 " ..... | 6 | 172 |
| Ditto ditto ditto ..... | 14 | 1 Portland cement... | 4 | 217 |
| Ditto ditto ditto ..... | 14 | 1 " ... | 5 | 304 |
| Ditto ditto ditto ..... | 14 | 1 " .. | 6 | 206 |
| Ditto ditto ditto ..... | 14 | 1 Lee's grey lime.... | 3 | 325 |
| Ditto ditto ditto ..... | 14 | 1 " .... | 4 | 336 |
| Ditto ditto ditto ..... | 14 | 1 " .... | 5 | 290 |
| Ditto ditto ditto ..... | 14 | 1 " .... | 6 | 303 |
| Prism of selenitic mortar 2 in. ×2in. × 4 in. long, and 3 in. between points of support..... | 209 | 1 Portland cement... | 3 | 668 |
| Ditto ditto ditto ..... | 209 | 1 " ... | 4 | 476 |
| Ditto ditto ditto ..... | 209 | 1 " ... | 5 | 344 |
| Ditto ditto ditto ..... | 209 | 1 " ... | 6 | 190 |
| Ditto ditto ditto ..... | 177 | 1 Barrow lime..... | 4 | 740 |
| Ditto ditto ditto ..... | 177 | 1 " ..... | 5 | 776 |
| Ditto ditto ditto ..... | 177 | 1 " ..... | 6 | 698 |
| Prism of Mortar, same dimensions as before, but not selenitic..... | 177 | 1 " ..... | 3 | 440 |
| Ditto ditto ditto ..... | 177 | 1 " ..... | 4 | 338 |
| Prism of selenitic mortar, same dimensions as before | 230 | 1 Lee's grey lime .... | 4 | 806 |
| Ditto ditto ditto ..... | 230 | 1 " ..... | 5 | 722 |
| Ditto ditto ditto ..... | 230 | 1 " ..... | 6 | 876 |
| Briquettes of selenitic mortar, breaking area 1¼ in. × 1¼ in. = 2¼ sq. in..... | 167 | 1 Portland cement... | 4 | 206 |
| Ditto ditto ditto ..... | 167 | 1 " .... | 5 | 149 |
| Ditto ditto ditto ..... | 167 | 1 " .... | 6 | 113 |
| Ditto ditto ditto ..... | 132 | 1 Roman cement .... | 3 | 232 |
| Ditto ditto ditto ..... | 132 | 1 " .... | 4 | 250 |
| Ditto ditto ditto ..... | 132 | 1 " .... | 5 | 124 |
| Ditto ditto ditto ..... | 132 | 1 " ... | 6 | 89 |
| Ditto ditto ditto ..... | 166 | 1 Medway grey lime . | 3 | 245 |
| Ditto ditto ditto ..... | 166 | 1 " .. | 4 | 147 |
| Ditto ditto ditto ..... | 166 | 1 " .. | 5 | 150 |
| Ditto ditto ditto ..... | 166 | 1 " .. | 6 | 108 |
| Ditto ditto ditto ..... | 76 | 1 Halkin lime ..... | 3 | 128.5 |
| Ditto ditto ditto ..... | 76 | 1 " ..... | 4 | 197 |
| Ditto ditto ditto ..... | 76 | 1 " ..... | 5 | 99 |
| Dilto ditto ditto ..... | 76 | 1 " ..... | 6 | 111 |

We give in the preceding table the results of a few experiments taken by us at random from the records of many thousands made under the superintendence of Mr. Gilbert R. Redgrave for Colonel Scott, in order thoroughly to test the efficiency of his invention. The early results were so remarkable that the Colonel was induced to repeat them over and over again, and to institute many others in order perfectly to satisfy himself of the correctness of his conclusions. The most searching trials, however, have only further demonstrated the importance of the invention, which is a thorough success and must prove invaluable in the constructive arts.

Samples of this cement were exhibited at the last Conversazione of the Institution of Civil Engineers, when a num-

ber of them were tested by Mr. Michele in his testing apparatus, and gave very satisfactory results.

As it is often found in practice that tiles bedded in Portland cement leave their setting, Messrs. Minton caused a series of experiments to be made with selenitic cement in order to test its adhesive qualities in this respect. A number of their tiles were joined together in pairs crosswise in the same way as the bricks, with two parts of ordinary Portland cement to one of sand. After allowing the joints to stand 14 days, a weight of 56 lbs. separated them, the cement in most cases coming clean away from the tile. With selenitic cement composed of 1 part lime to 5 of sand, the joint being 14 days old, it required a weight of 158 lbs. to overcome adhesion, and then the fracture took place completely through the cement, half remaining on each tile. With 1 of cement to 3 of sand, the breaking weight was 166 lbs., and with 4 of sand 165 lbs. ; the fracture in all cases taking place through the cement. These and the results given in the tabulated statement afford conclusive evidence of the superiority of the selenitic mortar over the ordinary compositions. We may add that a briquette of ordinary mortar composed of 1 part lime and 2 of sand, 6 months old, usually breaks at 70 lbs. or thereabouts.

## THE NATURAL HISTORY OF PAVING STONES.

By PROF. WILLIAMSON, F.R.S.

From "Science Lectures for the People."

When, some century and a half ago, the first excavations were made into the lava masses that covered the ancient city of Pompeii, it was discovered that the streets of the city had been paved with blocks of lava from the adjoining mountain Vesuvius. You have probably all heard of Macaulay's apocryphal New Zealander, who, in some future age, when England has passed its zenith, and is once more become a desolate wilderness, is to sit upon one of the broken arches of London Bridge to sketch the ruins of St. Paul's. And if that topographer of the future, when he accomplishes the task that the brilliant essayist assigned to him, visits the city which tradition indicates as having been the ancient seat of manufactures in this part of the country—I mean the city of Manchester—he, if he has assistants with him and should make similar explorations in the streets of this city, will have to record the same fact that has been recorded of ancient Pompeii. Unexpected as the fact may be even to you, he will have to announce that the streets of the city were chiefly paved with lava from an adjoining mountain.

Now before I demonstrate this apparently paradoxical statement, I must call your attention to the fact, which probably most of you know already, that there are two very different kinds of rocks found in the interior of the globe. There are, first, those that have been produced by volcanic fire—lavas—of an endless variety of sorts. There are, secondly, what are called the stratified rocks, that have been produced by the action of water. If you see a muddy pool deposing layer after layer of mud, and if when this mud subsequently becomes dried up, you proceed to examine the muddy deposit, you will find that it is arranged in layers. Now this deposit is on a small scale an epitome or picture of what is taking place on a gigantic scale in lakes and seas throughout the entire world. Every part of the world has been under water at one time or another; and the deposits that have been produced during countless ages have given us what we call the "stratified rocks." But you will probably like to have a proof of everything that is said from this platform. You may ask—How do you know that these deposits have been formed by water?

I wont dwell upon the subject ; I will merely say that where we find oysters, and mussels, and cockles, and crabs, and lobsters, we are pretty safe in affirming that the deposits which enclose the remains of those marine creatures must have been formed somewhere in the neighborhood of the place where these marine creatures lived. And so the marine remains of fossils that we find in these rocks clearly testify to the fact that the rocks in question

were formed by watery agency and under water. But you say, in the second place, even supposing we accept that proof as satisfactory, what evidence have you to give us that the other rocks were formed by fire? As this will be the special subject of a portion of my lecture to-night, we will take a little more trouble to demonstrate this fact to you, and make it plain.

The first photograph that I will show you is one from a drawing in a work recently published by Professor Silvestri, a work in which he gives an account of the changes that have taken place during the last few years through the eruptions of Mount Etna. Here you have a view of the summit of Etna; the central peak is here. I need scarcely tell you that you are looking down upon it as if from one of the balloon posts, about which we have heard so much latterly. All these round knobs that stand out so numerously and so prominently are so many craters that from time to time have burst through that mountain. There are hundreds of these craters, and a large number of them constitute even decent-sized volcanic mountains, scattered round the slopes of Mount Etna. Then these large black spaces, to which I would particularly call your attention, are areas where the lava has burst through some of these craters. Of course it has filled up the crater through which it flowed; but, in addition to filling the crater, it has overflowed its summit, and spread itself out in broad table-like areas over the sides of the mountain, and over the surrounding plains. Now, we have here an illustration of the kind of thing that these volcanic mountains exhibit. You may be somewhat surprised if I tell you that those slopes of Mount Etna are scarcely more pierced by craters and encompassed by deposits of lava than Wales is, in our own immediate neighborhood. There has been a time when Wales was almost as much disturbed by volcanic fires as Sicily is now. If you were to take a geological map of Wales, you would see that it is studded all over and in every direction with little red spots. Those little red patches are colors employed by geologists to indicate masses of ancient lava. Wales abounds in these masses. We find them on every hand, and it is to some of them, in the first place, that I shall have to call your attention to-night. I will show you a section of a part of Wales where we have volcanic rocks, and stratified or aqueous rocks, side by side, or rather, the one within the other. A section, you will understand, is that which you would have if I were to cut a Dutch cheese in two, and show you the cut side of it. If the Dutch cheese had happened to have been made of layers, piled upon one another like a pile of sandwiches, you would then have the edges of the layers revealed to view. But here, instead of sandwiches, we have a series of layers of stratified rocks; and, in the middle of them we have a great mass of volcanic lava. This is a mass of ancient lava from one of the Welsh mountains, with an unpronounceable name. I dare not venture to utter it. I should only fail; because, as you know, it is not easy to say which are consonants and which are vowels in the Welsh language, unless one is trained to it, which I was not. These are slate rocks. You will observe they are arranged in sloping layers, but these layers were originally horizontal. The reason why they slope upwards is that the volcanic fires which accompanied the outburst of this lava mass has driven up these stratified rocks, tearing them asunder, whilst the lava has forced its way through. We have several reasons for affirming that this lava was once fluid. You will observe that the lava has not only broken through these stratified rocks, but flowed upwards and downwards in all directions, filling cracks and crevices, which would not have happened had this lava not been fluid. Before I give you another section illustrating to you this action, let me show you a section of Snowdon itself cut in two. You shall also see the summit of Snowdon, which a kind friend who is in the room has brought to us. Then we have here a section of Snowdon. Here you have the extreme summit of Snowdon—the point to which many of you probably have been. You will observe that there are several series of rocks following each other. Now what, in the first place, are these purple-colored layers at the base? (The colors are merely conventional, for the purposes of the diagram.) They are beds of slate rocks. These yellow-tinged parts above them represent enormous masses of lava. Now, this mass of lava was once continuous over many miles of district. The reason why it is now isolated is this: after

spreading over many miles of district, it has been subjected to the action of currents of water when the whole was under the sea. These water currents have scooped out deep valleys, and swept away an incalculable number of square miles of solid materials. Parts of Wales that were once thousands of feet higher than they are at the present day, have been completely cleared away by this watery action—by what is technically called "denudation." This accounts for the interrupted character of these masses of deposit. The summit of the mountain is a mass of volcanic product; not lava, but ashes. It would appear as if the volcanic outbreak which had covered this part of the country with this peculiar kind of volcanic rock, had been followed by some outburst such as you meet with in volcanoes of the present day, in which an enormous quantity of volcanic ash has been deposited; and some of what escaped removal by denudation now constitutes the extreme peak of Snowdon. The next picture will show the peak of Snowdon as it now is. The difference between the present and the past is very considerable. I do not mean to say that the cairn is a volcanic peak; it is not; but the material upon which the wonderful cairn is erected is volcanic; it is made up entirely of volcanic ash. So that we have in Snowdon three distinct masses of material—the volcanic ash at the top; a mass of lava in the middle; and the water-derived slate rocks at the base. In the diagram I showed you just now, you saw a broad red band crossing the picture obliquely. Now this band is another kind of volcanic rock, and of more modern date than the others. You ask, "How do we know that?" Well, I think we may safely venture to say that that which goes through another thing, has come there subsequent to the time when that which it penetrates first existed. These rocks, you perceive, have been already deposited when some huge volcanic crack has been formed in them, and volcanic material has come up and filled that crack. Here we have evidence of successive outbreaks of volcanic action. Now I will show you the proof that this volcanic action was accompanied by heat. I think I have said enough to show that this material must have been fluid. The reasons why we conclude that that fluid must have been in a heated state like lava, are these: In the first place, wherever the lava has come in contact with any other kind of rock, it has entirely altered the character of that rock. If it has come in contact with coal, it has burned that coal into cinders; if it has come into contact with limestone, it has burned that limestone into marble; and if it has come into contact with slates, it has altogether altered the character of those slates, and given them a different appearance. I will show you an instance proving this point. The picture that I am now going to exhibit to you is a section of another part of Wales, derived, as most of these sections are, from the very able report on the Geology of Wales, by Professor Ramsay, and which was published in the Memoirs of the Geological Survey of England.

Here we have a series of slate rocks with a dyke of lava running through them. Here is a fragment of slate torn off from these rocks and imbedded in the lava. You will observe that the appearance of the slate immediately above and below the lava is altogether altered. The difference is this—one portion of the slate cleaves easily into roofing slates; but the layer in immediate contact with the lava has been so altered by that contact that it refuses to be so cloven. Now you have here a clear proof that the contact of the lava with the stratified or aqueous rocks has made an entire change in the structure of those rocks; and we know from examination that all these changes, wherever we find them, are precisely the phenomena that would result if the same rocks were exposed to the action of heat.

The next point that I will speak of is the more special subject of the lecture to-night. I am going to tell you about paving stones. As Professor Roscoe has intimated to you, it is a somewhat unpromising subject; and I confess I was rather disposed to approach it with a little fear and trembling. In Manchester, as I learn from our friend Mr. Stott, who has charge of this department, we use different kinds of stones for paving. I have here three stones of one kind, and several stones of another kind. Before going into details, I must remind you that we have in Manchester an ancient civilization and a modern civilization. If you go along the back streets of Ancoats and other parts of the town, it will be desirable, especially if the day be wet, to take care to have thick

shoes, because walking in thin shoes on the rounded boulder stones with which those older streets are paved is somewhat uncomfortable work. But our civilization has made our more modern streets very different. You know that they are paved with those square stones which I think are technically call "sets," stones which make a magnificent paving. The only complaint we hear about them is when our authorities do not supply the streets with quite sufficient water, and then the gentry who ride their horses or drive their carriages are a little disposed quietly to complain. But this is only one very insignificant feature of these stones. It is true they are apt to become a little slippery in dry weather; but on the other hand, they are exceedingly durable, and being durable they are eminently fitted for the purpose of the tax-payer, whatever they may be for the equestrian. I learn from Mr. Stott that we obtain these "sets" from three localities. Here is one stone that is obtained from Penmaenmawr. Here is another stone that has been obtained from the Clee Hills in Shropshire; and here is a third stone that is obtained from a part of Carnarvonshire, from the neighborhood of a place they call Glynnog. What are the rocks at these three localities? The Penmaenmawr and Clee Hill stones are very similar in their essential qualities; they are lavas, closely allied to the form we commonly call basalts and greenstones. I won't enter into the minute distinctions of these stones. I am not about to bewilder you by the wonderful chemical formulæ that my friend behind me (Dr. Roscoe) could favor you with, in describing the chemical composition of these stones; that would be out of my reach and line. Neither will I trouble you much with minute distinctions between one kind of basalt and another. There is an endless series of these distinctions that would perplex him still more to identify all the varieties when he saw them. All I have to do with them to-night is, to say that there are many kinds of lava, whether we choose to call them basalts or greenstones, or felspars or porphyries, or by any other of those mineralogical names which are employed to distinguish them. But we can draw a broad distinction between basalts, an ancient kind of lava, and granites, which are also an ancient kind of lava, but a very different one. Let us see what this Penmaenmawr stone is. It is a lava very similar in its essential composition to the lavas of modern times. Let us see what sort of appearance these rocks present as seen in a photograph. I have here two photographs of Penmaenmawr, a place that probably many of you have visited. One is a view from the north side, and the other a similar view from the south side. Here you have Penmaenmawr as it appears from the south side.

You observe that we have here a sloping plain. Now this plain consists chiefly of stratified rocks of various kinds. But you notice that Penmaenmawr is a huge rocky mass that rises up out of the plains—a huge boss. Now let us see the other side of Penmaenmawr. When viewed from the opposite side, it presents, precisely the same features as before. Here you have Penmaenmawr as seen from the village itself. You observe that from this side you again have a large plain, made up of stratified rocks, with this immense boss of lava that has been forced through from below. The section I am about to show you is from the very heart of a mountain called Mynydd-maior. It consists of substantially the same rocks as Penmaenmawr. Now notice the stratified rocks. They have been thrown into almost vertical positions by the outburst of this lava. When the denuding currents have swept over that country—as I have told you they have done, again and again, through countless ages—they have removed all those portions of the rocks that were softer than others; they have yielded to the action of the water, whilst the harder rocks have resisted it. Now this lava being harder than the stratified rocks, has resisted that action; and, therefore, it stands out like a huge boss from the surrounding plain, precisely in the same way that we have seen that Penmaenmawr stands out from the plain surrounding it. It is simply because this crystalline lava is very much harder than the rocks around it that it stands in this fashion; it has resisted the denuding action; the other rocks have yielded to that action. Here then we we have a clear illustration of the nature of the rock of which Penmaenmawr consists, and which we are using to a very considerable extent for the purpose of paving

the streets of Manchester. We will now leave Penmaenmawr.

Let us next see what we have got in the Brown Clee Hills. Mr. Stott informs me that the Clee Hills stone will serve our purpose better than the Penmaenmawr stone. He believes it to be a harder stone. But when we examine the conditions under which it was formed, we discover that it is substantially the same thing we have had before. Here you have a section of the Clee Hills. At the base we have a limestone, similar to that which you have in the hilly districts of Derbyshire. Then we have here the millstone grit—that coarse grit—stone found in the hills behind Oldham and Rochdale. Then, at the upper part, we have a coal field, furnished with seams of coal like those that we find in this neigborhood. But this red band running up through the centre of the section, and overflowing right and left, is really lava, very similar to what we have seen at Penmaenmawr, a crystalline basalt, which is spread out over a very considerable area, forming an extensive moorland district; and it is from this district that this Clee Hill basalt is now being brought to Manchester. Thus we see that the phenomena attending the formation of this Clee Hill basalt are precisely the same in all essential features as those that have attended the formation of the basalts in Wales.

We have now to look at the third stone. You are all more or less familiar with the name of granite. Granite has unquestionably been an ancient lava; but it has been rather different from modern lavas in a variety of secondary circumstances. We see very clearly, first from its composition, and second from its microscopic structure, that it has not been formed under the same conditions as the ancient lavas with which we are familiar. The probability is that it has been formed under greater pressure. Whether that pressure has taken place deep in the interior of the earth, or whether it has taken place, as some suppose, under a deep ocean, we have no means of knowing. But there are many minor and secondary features about it which indicate that the conditions which make granite different from other stones, have resulted from an enormous pressure. But then we have two kinds of granite. Common granite is made up of three minerals, known by the respective names of quartz, mica, and felspar. But the particular variety which I hold in my hand, is that known by the name of syenite; and it differs from other granite inasmuch as the mica of ordinary granite is replaced by the crystals called hornblende. This is not a matter of any very great consequence to us, except for this reason, that the hornblende being somewhat harder than mica, we may fairly expect that the syenite may give us a harder paving stone than the ordinary granite. We will see what this syenite is like when at home. Here is a section which exhibits to us the locality from which this syenite is obtained. In it we again observe that we have the stratified rocks thrown upon end. The fact is, these stratified rocks in Wales, as elsewhere, have been twisted and twined about almost as easily as you could twist and twine about layers of cloth or brown paper. The forces with which nature has altered the condition of these strata, have been so gigantic that any resistance these rocks could afford has amounted to very little indeed. This syenite, you observe, presents itself to us under precisely similar conditions to those we have seen in the case of basalt. It comes up from below, filling a huge crack; and if we examine the sides of the crack we shall discover that the heat of the fluid mass of syenite has altered the rocks just as the basalts and other lavas altered the stratified rocks.

We will now leave these "sets" and examine an altogether different branch of our subject. We must turn to the ancient Manchester paving, and this brings us to the boulder stones. We have to take into consideration two or three circumstances in connection with these boulder stones. I am informed by Mr. Stott, that in the olden time, when we were in the habit of importing boulder stones for all the streets of Manchester, they were chiefly brought from the sea coast of Cumberland. If you go to the sea coast, either of Cumberland or of any other land, you will find that it is frequently made up of rounded stones, anything but agreeable to walk upon; almost worse, if possible, than the rounded stones with which your older streets are paved. You might be disposed to imagine that all these rounded boulder stones had tumbled down from the cliffs above, and simply been rounded by the action of the

water, by the waves beating upon them year after year and century after century. And in the case of many of these boulders you would undoubtedly be right in so surmising. I don't know much about the Cumberland coast, but I could take you to the Yorkshire coast, about which I do know something, and could show you there precisely similar phenomena to those which appear on the Cumberland coast; and we have every reason to suppose that the essential conditions are pretty much the same in the two localities. When we visit these coasts, whilst we discover a large number of rounded stones derived from rocks forming the adjacent cliffs, we also discover mixed up with them a very large number of stones that are not to be found *in situ*, as we call it, that is in their natural position, within miles from us. Here, then, we clearly have to seek out some agent that has assisted the sea. There has evidently been some other power at work that has brought boulder stones to that Cumberland coast that were not there originally, and that were not derived from the strata of the adjoining cliffs. We find there granites and lavas, and an endless variety of other rocks that were not originally derived from the Cumberland hills at all; they have been imported into that district and subsequently re-imported from that district to Manchester. Now whence have these other stones come? It will simplify the matter, as the Irish song says, "altogether entirely," if we call your attention to a Manchester brick-field. You may ask, what on earth can a Manchester brick-field have to do with Cumberland boulders and the paving of Manchester streets? More than you would imagine at first sight. If I take a walk with you to a Manchester brick-field, we shall discover that we are most interested in precisely that part of the field that will be the greatest abomination to the brickmaker. The brickmaker likes the nice, smooth, soft clay, without any stones in it, which to the geologist is about as stupid a part of the field as he could have. The geologist, on the other hand, likes to find a place that is full of gravel and sand, and huge boulder stones of every shape, and sort, and size—the very abomination of the brickmaker. I have here certain boulder stones that were taken from a Manchester brick-field. What have I in my hand? A block of granite, which I carried painfully and laboriously one day from a brick-field in the neighborhood of Ladybarn. It is a mass of granite, rounded just like the rocks on the Cumberland coast. That granite has been transported from a considerable distance, because we have no granites nearer than Cumberland. The nearest granite we have to this locality is that of Shap Fell, in Cumberland. The granite from Shap Fell is a very remarkable granite, from the large crystals of flesh color which distinguish it. I have here, from this same brick-yard, a piece of Shap Fell granite. Why, I could swear to this piece of granite all the world over, as a man would swear to the face of his own wife, wherever he met with her. The features of it are so remarkable that you could not mistake it, if you knew what Shap Fell granite was. Now this Shap Fell granite, rounded and water-worn, has been brought to a Manchester brick-yard. How has it got there? I have here another boulder. There is nothing particular about the appearance of this boulder, except that it is a piece of limestone that never "grow'd"—if I may apply Topsy's word—in the neighborhood of Manchester. It, like these other stones, has been brought to Manchester from a distance. But it tells me another story. It has another tale to record. I see that this surface is grooved, as if covered with the marks of a file. I turn it round to the other side, and I see that it is filed and grooved in like manner; but these grooves are not parallel with the former grooves. Here is a second flat face. It is very evident that in some way both these faces have had a good scrubbing, that has involved something more than a mere washing of the face. I dare say we have some keen reminiscences of the sort of scrubbing we used to get from the nurse's hands with rough coarse towels; but that is nothing compared with the scrubbing these stones must have had. There has been an action which has flattened that surface and grooved it at the same time. We want some agency that will do all these things together. You will remember that when my friend Professor Huxley lectured here at the beginning of this series of lectures, he pointed out to you in a very clear and prominent manner, how absolutely necessary it was that any theory that was propounded to explain a multitude of phenomena should "go upon all fours;" that

is, it must be equal to the explanation of all the several isolated and detached facts that the theory is intended to explain. Now we want a theory that will explain all these things. We want a theory that will mix together rocks of all kinds, that will mix them up with clays and with sands, and with an endlessly varied set of materials. We want a theory that will make some of these rocks round and grooved and streaked. We want a theory that will explain why some rocks that are transported are as angular and as sharp as this specimen. In order to give you such a theory, I shall have to carry you half way across Europe. I will begin by taking you to Switzerland, and if you have as pleasant a voyage thither to-night as I had some months ago, I shall envy you the repetition of my enjoyment. Here is a photograph I took in one of the loveliest scenes in all Switzerland. Here you have the Mer de Glace, that great stream of ice which has been celebrated in almost all ages as one of the loveliest spots in Switzerland. The Mer de Glace belongs to that range of mountains of which the peak of Mont Blanc is the centre, and it is only a few miles away from that great mountain. This is a glacier. What do we mean by that? Those mountains which you see on all sides of the glacier are within the limits of perpetual snow; summer and winter, wherever there is a ledge upon which the snow can rest, it remains unmelted. This accumulation of the snow would in time entirely hide and bury the mountains, unless nature had provided some way for getting rid of the surplus. She has provided such a way. The pressure of the snowy mass on the upper parts, forces the lower snow down into the valleys. Then that snow, partly under the influence of the intense cold, and partly under the influence of the pressure to which the particles are subjected, becomes re-frozen, becomes consolidated, not into snow, but into a mass of solid ice; and by a wonderful series of changes, which my time will not allow me to explain, this icy mass flows down the valleys of these Alpine mountains, fitting itself to the various curves, to the widenings and narrowings of these valleys, almost as if it were a fluid. Indeed, so wonderful has been this peculiar power of the ice to adapt itself to the shape of the valleys, that the late Professor James Forbes, of Edinburgh, arrived at the conclusion that ice, hard as it appears to be when you are skating over it, must have possessed a certain property of viscosity, a certain kind of fluidity which enabled it to adapt itself to the various contours of the valley. Professor Tyndal, however, has given us a better explanation. He shows us that this downward steady movement is really accompanied by a crushing process, instantaneously followed in each atom by what he calls re-gelation, which means in plain English, freezing over again. The point we have to deal with is not this re-gelation. We may take the movement of the glacier as an accepted fact. These glaciers move from the higher valleys into the lower ones at a very slow pace, but one which is capable of being measured. But what takes place as they do so? These magnificent mountain peaks, composed in this instance chiefly of granite, are being continually disintegrated by the cold of winter, by the rain, storms, and various atmospheric agencies that affect the surface of the globe. Huge fragments come tumbling down from above, and of course these fragments fall from the ice. You will see running along here a band of rubbish that has fallen from above. You will see along here another band of rubbish that has fallen from above on the opposite side. The next photograph is one I took of the same spot in the immediate neighborhood of what is called the *moraine*, or, in other words, this band of rubbish. Here you have the mountain slopes that we descended. We crossed over these huge rocks. Here you see the ice-slope which we had to climb in order to get upon the glacier. You see here what kind of materials the moraine consists of. The whole of this mass of rubbish is resting, not upon the ground, but upon the ice, so that, as the ice moves, it carries all these rocks along with it, just as easily as you would carry your hat upon your head, and if it is one of the chimney-pot hats, I venture to say, an enormous deal more easily! This is what is called a lateral moraine, one running down each side of the glacier. There are other moraines. The next photograph that I will show you is from another glacier in the Chamouny valley—another of the Mont Blanc glaciers; but it shows a different part of the glacier. This is a very instructive picture to those who have

not visited the real scene. Here is the lowermost part of the ice; here is the cavern from which the water issues—there is always a torrent of water rushing down—and here we have what is called the terminal moraine. You will understand that when these masses of ice come down from the cold valleys above into the warm valleys below, the ice necessarily melts. Were it otherwise, those splendid scenes would become simply one sheet of polar ice. It melts, but the stones that it carries won't melt; consequently they have to stay there. As the ice melts, these stones drop down; and here you might almost imagine that you see them in the very act of dropping. These are stones that must have fallen almost the very day that I was there. Here is a glacier covered with ice; here are all the stones that form the moraine; here is the melting ice breaking off in blocks, and, as the ice breaks off and melts, the stones that break off with it tumble down as you see here. Now, you observe that in this way we have brought down to the lower valleys enormous quantities of material that lately had their home on the peaks of the mountains and in the valleys above. In this way we see that the glaciers not only receive from the mountains on each side immense masses of rock, but that they carry these masses of rock along with them down to the lower valleys. There is no doubt whatever that a very large quantity of material that we now find spread over the surface of the globe has been conveyed in this way.

But this alone would not account for the phenomena of our Manchester brick-fields. We want something more. We have evidence clear as the sun at noonday, that the material of which our Manchester brick-fields, and the brick-clays over a great part of the world, are similarly composed, have been brought thither by water. They have been deposited under water. We frequently find sea shells in them. We have the clearest evidence, I repeat, that these remains have been accumulated under the sea. Unless we can bring our glaciers in some way into contact with the ocean, our theory will not fulfil Prof. Huxley's requisition—it won't "go upon all fours." Let us see if we can find proof of that contact.

We will now transfer ourselves from Switzerland to Smith's Sound, in the Polar regions. Here is a drawing I have copied from one of Dr. Kane's sketches. Here you have what is intended for the sea. If you saw it in daylight, it would be a proper sea green. Here you have the rocks and lofty cliffs that surround the part of the country in which the phenomena I am about to explain exist. In the extreme winter these masses of ice extend right across the Sound, from side to side. As the summer approaches, the central ice breaks up speedily, and floats away; but long belts of ice hold their ground around the coast for a considerable part of the year, and sometimes they fail to break away from one season to another. Now these blocks, or masses of ice, technically called "ice belts"—because they belt round the coast—receive masses of rock in precisely the same way as the glaciers did in Switzerland. Thus we see that these blocks of ice would carry away with them blocks of stone, if any circumstances occurred to detach the ice from the land. The detachments take place perpetually, and they carry away with them these blocks floating upon their surface. They are huge ice-rafts, which sail southwards, impelled by Arctic currents. But this is not all. We have some glaciers in these polar regions, of precisely the same nature as those of Switzerland; but, instead of the polar glaciers being comparatively diminutive—$\frac{1}{4}$ or $\frac{1}{2}$ a mile across—the great Humboldt glacier is 50 miles across, from one side to the other, and yet that Humboldt glacier, which comes right down into the sea, is bringing stones along with it in precisely the same way as the other glaciers. Now, with such prodigious masses of stone-covered ice as this existing in the northern seas, you will not wonder that from time to time icebergs of the most gigantic size are met with floating out of those northern bays and straits. Remember that what are called icebergs are merely either fragments of this belt of ice of these Arctic glaciers broken away, or portions of that huge mass of ice which in winter covers the whole of those regions—when you see that these ice formations exist on so gigantic a scale, you will not wonder that icebergs are met with in these seas, sometimes a mile in extent. If you realize that, when you have an iceberg of this size, it floats with its summits 200 or 300 ft. above the sea, and that it sinks below the water some 6 or 8 times its elevation, I think you will

readily understand how that floating raft would be able to carry a very considerable slice of Penmaenmawr upon its surface! I have here a picture of one of these floating rafts copied from Dr. Kane's book. I have represented it as well as I could. Here you have the ice, which has upon its surface huge blocks of solid rock. This was sketched by Dr. Kane as he saw it floating away into the southern regions. It is an exaggerated example; we do not usually see the rocks so huge in proportion to the size of the raft, but it will give you an idea of the kind of transporting power these ice rafts have.

Now let us see how all this applies to English scenery. I have told you that the glacier moves steadily down the valley. You saw from the diagram that the glacier is cut up by deep fissures, called crevasses, that go down frequently to its very bottom. The stones that appear upon the surface of the glacier fall into these crevasses, and at the bottom they become entangled in considerable numbers in the solid ice. Many of them are angular. But you will also understand that if that vast mass of ice, filled with stones, is moving steadily downward over the rocks of which that valley consists, those stones will act like the teeth of a huge rasp; that they will plough, just in proportion to their size and sharpness and hardness, deep grooves in the rocks along which the ice is travelling. The stones themselves, being imbedded firmly in the ice, will scratch and scour over the rocks over which they move; and this is precisely what we find that they do. Sometimes the ice retreats, leaving behind the smooth and polished rocks, over which it formerly travelled; the changes of the seasons frequently lead to its doing so; the glaciers not unfrequently recede up the valleys in hot seasons and come down again in cold ones. When the ice recedes we see that the rocks are scoured and grooved and polished in the way we should expect them to be. But if they receive this rough sort of treatment, what might we expect to be the result upon the teeth of the rasp? Workmen know perfectly well that when they use their files upon hard metal the angles get worn off. It has been so here. We could readily understand that if this stone was imbedded in the ice, and formed one of the teeth of our great Arctic rasp, that its surface might well be flattened and grooved with longitudinal grooves. Here, then, we have an agent capable of producing grooves. Then, if these icebergs float upon the ocean, carrying rocks with them, they will travel southwards, carried by currents, and, as they come into warmer regions, they will share the fate of the Alpine glacier. Floating upon the sea does not save them; they melt little by little, and as they melt, the rubbish that they are supporting falls to the ground. The fact is, we have here a grand Arctic Limited Liability Carriage Company! and it is one in which the liabilities, in a financial sense, are at a minimum and exceedingly small, whilst the transporting power is at its maximum, or exceedingly great. If we were shareholders in a limited liability company, these would be just the results that we should like to attain to if we could. Inasmuch as the floating rafts cost nothing, it is of no consequence to the company that they melt, and that whatever they carry goes to the sea bottom. If they were bringing our trunks from the Arctic regions, we should find out the difference between them and a good old wooden ship. But they melt, and whatever they sustain, trunks or stones, goes to the bottom. The result is that large portions of the sea bed are being strewed over with blocks of stones — angular blocks, rounded blocks, sand, rubbish, every conceivable kind of produce that those northern mountains furnish is being gradually brought southward, and scattered over the bed of the Atlantic at the present day. And precisely similar phenomena were taking place during one of the latest of the geological periods when nearly the whole of our island was under the sea. There was a time, comparatively recent, geologically speaking, when our island was under the sea, but when the mountains of Wales and Scotland stood out like islets from the Arctic ocean. The great valleys of Snowdon were filled with these glaciers. If you go up the pass of Llanberis, you will see on every hand the indications of the fact in the rounded rocks, and in their scored surfaces, that abound on each side of the road. A little above the village you see them beautifully exhibited; and in the same way throughout in the district of which Snowdon is the centre, you have

these indications of glacial action so numerous and so clear, that not a shadow of a doubt remains that the Snowdonian valleys, as well as the valleys of Cumberland and Scotland, were, at the time of which I am speaking, filled with ice glaciers. Now all these glaciers—along with others coming from hundreds, not to say thousands of miles away, as well as from mountains in the immediate neighborhood—brought their produce to the same bed of the ocean, and as it was all tumbled down into one common mass, you find materials in the shape of mud and sand as well as coarser materials, including both rounded and angular blocks, accumulated in the same sea bed. Now I think you will see that I have brought before you an explanation that fully accounts for the miscellaneous kind of admixtures that you find amongst the sand, and clay, and gravel beds whether of a Manchester brick-field or of the coasts of Cumberland and Yorkshire.

Ladies and gentlemen, I have now finished my task. I have endeavored, I trust not altogether unsuccessfully, to show you that in the natural world there are no objects, however common and familiar, that cannot reveal an interesting story, if we are but intelligent enough to question nature in a right manner. Many of you are occupied with manufacturing pursuits, and, from time to time, your workshops receive the visits of strangers, who look with intelligent interest upon the processes in which you are engaged, and upon the final products of your labors. I invite you, in like manner, to visit nature's workshop. She, too, is a fellow-laborer with yourselves; only, unlike you, she needs no rest, but works on, with untiring energy, day and night, summer and winter. She usually toils so noiselessly that few men know the vastness of the forces at her command. When we float idly upon a summer sea, or recline in some sheltered nook, watching the tranquil glories of a July sunset, we reck little of the fearful energies that underlie the present calm. It is only when nature rouses herself, like some angry lion, that men recognize her terrific powers. It is when the reeling earth is shaken by the earthquake, and cities crumble into dust; when the volcano belches forth its showers of ashes and streams of liquid fire, hiding the prostrated ruins from the eyes of men; when the flashing lightnings and the grand roll of the thunder inspire the stoutest hearts with wonder, not unmixed with awe; when the stormy ocean and the flooded river inundate the land, tossing man's proudest works, like playthings, from their surface, and hurling them to destruction, then it is that we learn something of nature's power. Yet these forces, at times so terrible, are ever working out their Divine Creator's will and ministering to human wants. Study them and they will interest you; examine their products and they will repay you. You will then recognize the truth of the words which our greatest dramatist puts into the mouth of his banished duke, when he declares that there are

> Tongues in trees, books in the running brooks,
> Sermons in stones, and good in everything.

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CAMEL'S hair is imported from Persia chiefly through the Russian ports, and is mostly used in the manufacture of pencils for drawing and painting. Camel's hair is longer than sheep's wool, and often as fine as silk. There are three kinds of colors, black, red, and gray, the darkest of which is considered the most valuable. It is said that the hair on a camel weighs about 10 lbs. In Bokhara the camel is watched while the fine hair on the belly is growing. This is cut off so carefully that not a fibre is lost, and when sufficient has been collected it is spun into a yarn unequalled for softness, and then dyed all manners of bright colors, and used chiefly for shawls. The Arabs and Persians make of camel's hair, of a less valuable kind, stuffs for carpets, tents, and wearing apparel, and cloth is made of it in Persia.

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SEVERAL important public works have been projected for Alsace and Lorraine, the execution of which is to be shortly commenced. The principal of these are the canalization of the Moselle, which, according to the estimates, will cost 8,000,000 thalers (30,000,000 francs), and the excavation of a canal uniting Strasburg with the Rhine. Some of the intended improvements have been repeatedly promised by the French Government.

# APPLICATION OF AMMONIACAL GAS AS A MOTIVE POWER.

By EMILE LAMM.

Ammonia, at the temperature of our atmosphere, is a permanent gas of well-known pungent odor. It is formed by the union of three volumes of hydrogen to one of nitrogen, condensed into two volumes. Its density is 596; air being 1,000. The density of the liquid, compared with water, is 76, or about one-fourth lighter than that liquid. Its vapor, at 60 deg. Fahrenheit, gives a pressure of 100 lbs. to the sq. in., while water, to give an equivalent pressure, must be heated to 325 deg. Fahrenheit. The volume of ammoniacal gas under the above-named pressure is 983 times greater than the space occupied by its liquid, while steam, under identical pressure, occupies a space only 303 times greater than water.

The above figures are taken from a work published in Paris by the editors of the "Annals of Civil Engineering," and have been substantiated in a lecture delivered by Mr. Poullet, before the French Academy of Sciences, on the apparatus of Carré for making ice by means of liquefied ammonia.

The latent heat of ammoniacal gas is 860, that of steam being 990. Ammonia is a powerful alkali. It rivals potassa and soda, and can neutralize the most powerful acids. Its action upon most of the metals is null; still, strange enough, it acts slowly upon one of the metals of the second class—*i. e.*, copper. Upon metallic iron, which is a metal of the third class, its action is absolutely null; but readily dissolves carbonated oxide (iron rust). Ammoniacal gas is absorbed by water with avidity—one volume of water at 70 deg. Fahrenheit, absorbing 500 volumes of the gas. The water becomes specifically lighter, while its volume is being augmented about one-third. As the absorption of the gas goes on, the water becomes heated, and the latent heat of the gas reappears as sensible heat. It is in this property that water possesses of absorbing so large an amount of the gas, and of becoming heated while absorbing it, that the practicability of using ammoniacal gas as a motive power rests, for it must be well borne in mind that the only agency for producing motive power is heat.

In 1833 Mr. Faraday discovered that ammoniacal gas was the vapor of a liquid which boils at 40 deg. below zero Fahr. The vapor of this liquid exerts a pressure, in a close vessel of 100 lbs. to the sq. in. at 60 deg. Fahr. The experiment is performed in the following way: A glass tube is procured, bent in the shape of the letter Λ, inverted, the end of the tube "a" is filled with a concentrated solution of aqua ammonia, from which the air is expelled by a gentle heat. The open end of the tube "b" is then sealed, after which the end "a" containing the solution is heated by means of an alcohol lamp, while the other end of the tube "b" is made to dip in a bowl of cool water. The gas expelled from the aqua ammonia, gradually accumulates on the top of the liquid, and when it comes to exert a pressure of 100 lbs. to the sq. in., the water in the bowl being at 60 deg. Fahr., it rapidly condenses, in the cool end "b" of the tube, into a highly volatile, clear, colorless liquid. After the experiment is concluded and the fire removed, and as the now nearly pure water, from which the gas has been expelled, gradually cools at the end "a" of the tube, the liquid ammonia boils in "b" and is rapidly reabsorbed in "a," leaving after a short time no trace of the experiment.

If the end "a" of the tube be made to cool rapidly by being turned around and placed in the bowl, the liquid ammonia in the bend "b" of the tube outside begins to boil violently, and the tube, by the rapid evaporation of the gas, is soon covered with ice from condensation of the moisture of the atmosphere around it, while the water, which now re-absorbs the gas in "a" becomes as much raised in temperature as "b" falls. By keeping well in mind the simple instrument which served Mr. Faraday's purpose for liquefying ammoniacal gas, the process now in use for the purpose of liquefying the gas for running street cars will easily be understood. Let the reader imagine that each end of the bent tube is enlarged, one end "a" being a large boiler, or retort, containing a concentrated solution of aqua ammonia, the other end "b" a large receiver, or condenser. If heat

is now applied to the boiler containing aqua ammonia the gas will be expelled from the solution if water at a temperature of 60 or 70 deg. Fahr. be thrown upon the condenser; the gas, after the pressure on top of the solution has attained 100 to 110 lbs. to the sq. in., will be forced, by the tension of its own particles, into a liquid, in the condenser. This larger operation resembles in every particular that of the glass tube. But when the operation is concluded in the practical still, communication is cut off by means of a faucet between the boiler and condenser, and the result is a large quantity of liquid ammoniacal gas, ready to be used at any subsequent time for the purpose of running street cars or anything else as required.

Now that I have given a short history of ammonia, and how it is converted into a liquid (this liquid being always ready to fly into gas or vapor when it is at a temperature of above 40 deg. below zero), let us suppose that a car is to be run from a station and back, a distance, say, of 10 miles. A vessel resembling in shape, say, a soda fountain, is filled with 15 gallons of liquid ammoniacal gas, which will be ample for the trip. The liquid is taken from the still by means of connections similar to those of water pipes; the fountain is permanently fixed on the car and connected to a small locomotive engine in the same way as a steam boiler.

Now, the whole invention consists in immersing the fountain filled with the liquefied gas on the car, in a tank containing some of the water which was left in the boiler "a" of the still. This water, or weak solution, is put around the fountain at any temperature desired—warm enough in winter to counterbalance the effects of the atmosphere; and it is easy to perceive that the boiling of the liquid in the fountain is in no way dependent on the heat of the air, but solely on the temperature of the water surrounding it.

I have yet to explain how the problem of working ammoniacal gas instead of steam was solved.

To comprehend fully the relation of heat to matter, some degree of mental application is necessary, for the first impressions created by our senses are liable to be erroneous. The insurmountable difficulty, hitherto, in the way of using liquefied gases as a motive power, has been the impossibility of supplying, without a recourse to artificial means, the heat necessary to convert their liquids into vapor. The point at which such a liquid may boil below the common temperature, making but little difference practically between the heat necessary to evaporate into steam a given amount of water, which boils at 212 deg. Fahr., and one that boils at 40 deg. minus, such as ammonia; the real and only difference, comparatively, being that of radiation in favor of the liquid which boils at 40 deg. minus, this radiation in summer being 120 deg., while the radiation against the evaporation of water would be 132 deg. Fahr. And even the above differences are more apparent than real, for they would only exist at the start, or when artificial heat would begin to be applied; for it is well known that our atmosphere transmits heat extremely slow. For example, we have but to observe the fact, how slowly a piece of ice melts when exposed to the air; this is owing to the great amount of heat absorbed during the process of liquefaction, and which mere radiation from the heat of our atmosphere is unable, even on the hottest day of summer, rapidly to supply. How much more heat, then, is required to convert a liquid into a vapor, need not be dwelt upon; and hence the absolute necessity of finding, even with liquids of very low boiling point, a means of heating other than the atmosphere in order to supply the heat necessary to their practical application for the production of power in lieu of steam; for if it was necessary to heat ammonia on a street car by means of a furnace, ammonia, then, would offer but little advantage over steam.

But ammoniacal gas possesses the remarkable property, from its affinity for water, of being able at any time after its condensation into a liquid, to re-produce at a distance from the furnace and still where it was condensed a force equal to the heat which was necessary for its condensation. This re-production is owing to the fact that the latent heat of the gas appears anew as sensible heat in the water of re-absortion, and is re-transferred to the liquefied gas.

In a trip of seven miles made by a street car driven by ammonia, the engine used on the car was equal to 2-horse power

and the ammonia expended during the trip amounted to $1\frac{16}{100}$ cubic ft. The latent heat of ammoniacal gas being 860, the whole heat expended during the trip would have been sufficient to raise 84 galls. of water from the temperature 83 Fahr. to the boiling point of 212 deg. If for supplying this heat it was necessary to rely upon the heat absorbed from our atmosphere, even on the hottest day of summer, I am positive that a car loaded with passengers could not run more than 300 yards without being obliged to stop, and wait at least 15 or 20 minutes in order to acquire sufficient heat from the atmosphere again to run an equal distance. In overcoming this difficulty, lays the gist of the whole invention. The exhaust pipe leads into an outside shell or water tank, in which is immersed the reservoir containing the liquefied gas. This ammoniacal gas escaping from the exhaust pipe, after having acted upon the piston of the engine, as soon as it comes in contact with the water in the tank, is instantly reabsorbed, giving out at the same time the heat which was rendered latent by its evaporation in the reservoir; and, since both the latent heat of a vapor and the sensible heat which it gives back, when condensed into a liquid again, are equal in quantity, there is really no heat lost in the apparatus while the engine is working, except the mechanical equivalent of the power produced; but a continual retransfer of sensible heat goes on to supply the heat which is rendered latent by evaporation.

This retransfer of heat is not instantaneous, and to overcome the delay in the communication of heat between the continually cooling liquefied gas and the water becoming as quickly warm on the outside of the reservoir, it was necessary to construct a boiler of numerous tubes, so as to increase the heating surface. To obtain the dynamical effect of a gas or vapor, all of the latent heat which may be extracted from it must be added to it as sensible heat. For example, if a volume of air be taken at the existing temperature, and compressed into one-half of the space it occupied originally, it will become hotter, and the degrees of heat indicated by the thermometer above the common temperature shall be the equivalent of the force of compression. Now, if this same volume of air, compressed into one-half its original bulk, be allowed to cool until it is in equilibrium with the surrounding objects, it will have lost much of its tension, and the original tension or force of the air, existing at the moment immediately following compression, can only be given back to it by heating artificially above the common temperature to the same degree of heat it possessed immediately after compression. The force which a given quantity of liquefied ammonia (contained in a reservoir) exerts upon the piston of an engine in developing 1-horse power, for an hour, at the temperature of 60 deg. Fahr., provided it be kept up, is equal to the heat necessary to distil the same quantity of ammoniacal gas from the solution of aqua ammonia under a pressure of 100 lbs. to the sq. in., at a temperature of 212 deg. in the boiler and 60 deg. Fahr. in the liquefier.

It can be laid down as an invariable principle that the same cause (circumstances remaining the same) produces the same result. But what are the circumstances of ammonia compared with steam? Both steam and ammonia are governed by a law (the law of Mariotte), which is essentially the same for all gases, viz., that all gases or vapors expand equally by the the same addition of heat.

The mechanical equivalent of heat expended in working the engine by ammoniacal gas, $\frac{1}{7}$ of the total heat, according to the best physicist, is fully made up by the extra heat of chemical combination becoming also sensible at the instant of the reabsorption of the gas in the water surrounding the tubes. The register of the pressure gauge at the moment of starting and during the trip, shows conclusively that the extra heat compensates all losses. The mean pressure during a trip remains essentially the same, if we take into account the time necessary for the transmission or equalization of heat between the reservoir containing the liquid gas and the reabsorbing water in which it is immersed.

On the trip mentioned above, the gauge registered at the start 120 lbs., and was the same at the end of the trip,—at no time indicating a variation of more than 10 lbs. to the sq. in.; and this has since been confirmed by over 300 trips.

If the reader refers to what has already been stated concerning latent and sensible heat, he will remember it is proved in substance, that the sensible heat which is

abstracted when the particles of a liquid go off in the form of vapor, and which enters into that vapor as latent, would again be returned to the liquid as sensible if the vapor could be recondensed in the liquid itself. In nature there are many gases which can be liquefied, and when they are compressed into liquids, at the ordinary temperature of the atmosphere, these liquids have then a tendency to resume the gaseous form, but are restrained by a pressure which equals in some of them 1,000 lbs. to the sq. in. These extremely volatile liquids boil at a temperature so low that, in such an atmosphere, a human being would quickly be frozen to death. If there are substances in nature with such enormous pressure at ordinary temperature, why are they not used as motive power, when, it naturally springs to the mind, the atmosphere would supply the fire? This is a delusion; the atmosphere could not keep them boiling for 5 minutes. Let us inquire into the reason. If we wish to operate with a liquid that boils at 100 deg. Fahr. below zero, our atmosphere would then be equal in summer time to a fire of 170 deg. It is only necessary to consider that it requires 1,800 deg. above the boiling point of water to produce steam with sufficient rapidity for the working of an engine, to see the utter impossibility of producing the same effect with a fire only 170 deg. above the boiling point of a liquid which obeys the same law as water. Furthermore, it should be stated that heat is imparted by a warmer body in contact with a colder one, in a space of time which is in the inverse ratio of the square of their intensity.

The above remarks show that the heat which the atmosphere can impart is always trifling in any given time when compared to that of an artificial fire, and this deficiency is owing really more to its slow transmitting power than to the difference in its actual intensity for the purpose required. For, if our atmosphere possessed a transmitting power even equal to that of water, its low intensity would then be made up by its increased capacity for transmitting heat. This might seem to be at variance with what I have just said above; but a more intimate knowledge of the physical properties of air and all gases in general, would make it perfectly clear to the reader. Air and all gases are the most imperfect conductors of heat we know of. If air could transmit heat as rapidly as water, it would only require 375 deg. instead of 1,800 deg. of heat under the steam-boiler to produce an equal effect; but as heat travels 60 times faster in water than in air, the intensity of the heat passing through the air must be 60 times greater to produce the same effect in the same time.

All truly scientific men contend, at present, that there is but little advantage in developing a force with a liquid that boils below the boiling point of water, for, say they, in their beautiful, concise language, "the sum total of latent and sensible heat of a liquid is a constant quantity at all temperatures it may be subjected to."

Now, the above being an absolute truth, there exists a liquid which can carry away from the furnace that produced it all of the heat imparted to it, and can then reproduce this same heat and its equivalent force without loss. This liquid is ammonia.

As has been shown already, the ammonia is driven off by heat from the aqua ammonia at the station. If the fountain, that contains the liquid ammonia, was to be put in one side of the car, and the water that surrounds it in the opposite side, their arrangement with the engine still subsisting, *i. e.*, that the pressure-pipe should come from the fountain, and the exhaust-pipe dip into the tank, the liquid ammonia would soon be too cold to give any pressure, and the water in the tank too warm to absorb any more gas; so that the result would be, on the one hand, the stoppage of the engine on the road from the liquid, that furnished the vapor, ceasing to boil; on the other hand, the water of re-absorption would become so hot that in order to maintain its power of absorption water would have to be carried on the car to throw upon and cool the re-absorbing vessel.

Now, we neither stop on the road, nor carry extra water to cool the re-absorbing vessel, nor use a furnace on the car to heat the liquid ammonia, but simply put the vessel having a tendency to become too cold, in the one which inversely is becoming too warm; this will equalize the temperature, and the car moves to the end of the trip.

A further advantage which ammonia possesses over steam, is the fact that its vapor, not being condensed at the usual temperature of our atmosphere, does not, like steam, at a low temperature, suffer condensation either in the cylinder of the engine, or when used at a distance from the boiler. The last remark leads me to speak of the cheapness of ammonia as a motive power, especially where only 1 or 2-horse power is required—such as on street cars. Its cheapness, when compared with steam, is owing to the fact that one steam-engine, if it could be made to propel 100 street cars with ease, would be much cheaper than 100 steam-engines, each requiring a separate fire and an engineer, besides the regular conductor of the car; but the case is far different with ammonia, as a single engineer at the station can superintend the supplying of 200 cars with liquefied ammonia in sufficient quantity to run any distance within the limits of a large city, by means of a single fire under the stationary boiler from which the ammoniacal gas is liquefied. Further, liquefied ammonia can be compared, if I may be permitted the expression, to a bottled-up power, which can remain in a reservoir for months or even years, and be transported anywhere in any desirable quantity; and then, at once, without any further preparation, can be used for any purpose desired; and by the simple turning of a faucet can be made to act as powerfully as when first liquefied.

Practically, a large central depot could be cheaply erected with apparatus of capacity to liquefy a quantity of ammoniacal gas sufficient to propel all the street cars of a large city or other machinery. In thus indicating, in a general manner, the various applications of ammonia as a motive power, I must not forget to point out some other advantages which render it commendable:

*First.*—Its perfect safety—for the reason that its power is exerted at a very low temperature; for it is a fact known beyond dispute, that the main agency which causes those frequent and deplorable explosions of steam boilers, is the high heat they require for the production of an effective force.

*Second.*—The fact that it preserves iron indefinitely, while water, as is well known, will destroy that metal rapidly. In view of these advantages it is difficult to say where the application of ammonia as a motive power will stop.

REPORT OF A COMMITTEE OF ENGINEERS UPON THE PERFORMANCE OF DR. LAMM'S GAS ENGINE.

NEW ORLEANS, LA., *June* 1, 1871.

DEAR SIR,—At your request we made, on the 23d ult., an examination of your ammoniacal gas engine, attached to a car of the City Railroad Company of this city, and we inquired also closely into your gas generating apparatus located at the depot of that Company on Canal street.

Your invention cannot be better described than in the language of your patent No. 105,581, dated July 19, 1870: "The first part of my invention relates to an addition made upon the steam engine, of water chambers inclosing the piston rod and valve stem, so as to render it capable of being worked by ammoniacal gas instead of steam without any loss whatever of the gas, which is returned to the common tank, where the exhaust is re-absorbed by a weak solution of aqua ammonia.

"The second part of my invention relates to the application of liquefied ammoniacal gas contained in a considerable number of iron tubes, as the liquid from which, instead of water, the motive power of the engine is derived.

"The third part relates to a weak solution of aqua ammonia, contained in a tank, in which the iron tubes mentioned above are immersed, and in which also the exhaust pipe of the engine is made to dip near the bottom. The gas exhausted while the engine is working is re-absorbed by this weak solution of aqua ammonia until the solution becomes saturated. The gradual re-absorption of the gas by the weak solution causes the latent heat of the gas to re-appear, the consequence being the re-transfer, by means of the several aforesaid metallic tubes (or surfaces) of the heat thus given out in the weak solution, to the liquefied gas. This re-transfer maintains a constant temperature within the tubes, the result of which is to keep an undiminished pressure above the surfaces of the liquefied gas, notwithstanding the expenditure of the gas in working the engine.

"It can then be easily perceived that the boiler of this novel motive power is

composed of two parts, viz.: First, a tank or shell; second, the tubular reservoir therein contained. There is no communication between those two parts, except through the engine.

"The tubes contain the liquid from which the motive power is obtained. The tank contains a solution which re-absorbs, as it comes through the exhaust pipe of the engine, the gas volatilized within the tubes. The ammoniacal solution surrounding the tubes becomes, by a remarkable phenomenon, as soon as the machine is set in motion, the furnace which maintains, by an easily regulated heat, the motive power at its maximum of tension.

"The fourth part relates to the general application of the invention, the most important of which, at the present time, appears to be the propelling of street cars, for which purpose it will certainly prove very economical, though I am satisfied that it is equally applicable, as a motive power, for all purposes whatever, and especially to the driving of machinery requiring only an intermittent action.

"By means of this invention any number of cars can be propelled, without fire thereon, for any reasonable distance, for liquefied ammoniacal gas gives a pressure, at the mean temperature of our atmosphere, of 100 lbs. to the sq. in., and can be readily and economically liquefied under pressure by a process now well known in the arts. For example, the cars can be propelled at the expense of one single fire, heating, at the depot, a large feeding boiler containing a concentrated solution of aqua ammonia.

"The process of liquefying the ammoniacal gas is rendered continuous by a fresh concentrated solution constantly pumped back into the boiler to replace the weak solution which is drawn off from its bottom. The process for a continuous supply of liquefied ammoniacal gas being well known, is here mentioned only for clearness' sake.

"The tubes in the inner reservoir are filled with liquefied ammoniacal gas, and the outer tank is two-thirds filled with a weak solution of aqua ammonia. The engine is now in condition to communicate motion, by pulley or any other gearing, to any machinery or vehicle, by simply opening the valve, and it works along as if propelled by steam, until the liquefied ammoniacal gas in the reservoir becomes exhausted.

"Now, as each car, has partly expended the gas contained in the reservoir, said gas having been during the trip absorbed by the weak solution of aqua ammonia, this now saturated solution is pumped back, at the depot, into the feeding-boiler for redistillation. The reservoir is then charged anew with liquefied gas, the tank resupplied with a weak ammoniacal solution, at a proper temperature, drawn from the feeding-boiler; the car is then ready for the trip. Thus, the expense of propelling an unlimited number of cars is that of the fuel and labor necessary to heat the feeding-boiler at the central depot, and the annual loss of ammoniacal gas, which does not exceed 25 per cent. of the quantity required for each car.

"A further proof of the economy of working liquefied ammoniacal gas, instead of steam, is derived from this fact, that 1 gallon of liquefied ammoniacal gas, under a pressure of 6½ atmospheres at 50 deg. Fahrenheit, expands into 983 volumes of gas; while water, under the same pressure, at 320 deg. Fahrenheit, only gives a volume of 295 of steam to one of water; also, the quantity of coal necessary to evaporate 3 gallons of water will produce 4 gallons of liquefied ammoniacal gas."

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*The following remarks relative to Ammonia are derived from various authentic sources.*

Ammonia is composed of 3 parts of hydrogen and 1 of nitrogen—the product condenses to half its constituents. Under ordinary temperature and pressure, water dissolves or absorbs ½ of its weight, or about 670 times its volume.

The aqueous solution (aqua ammonia of shops) contains about 20 per cent. of its weight of ammonia.

Ammoniacal gas condenses into a colorless liquid at 38.5 deg. Fahrenheit under the pressure of the atmosphere, or 14.7 lbs. upon the sq. in. (which is the pressure under which all liquids boil), and it freezes to a transparent solid at 103 deg. Fahrenheit.

The solution ("aqua ammonia"), containing 670 volumes of the gas, has a specific gravity of .850; that of spirits of hartshorn is .960.

The solution absorbs 126 units of heat in its evaporization, while water absorbs 5 times as much, or 630 units.

The common "aqua ammonia" boils at 120 deg. Fahr., and it affords a pressure of 6 atmospheres at 232 deg. Fahr., while steam requires a heat of 320 deg. Fahr. to produce the same result.

Three lbs. of coal evaporates 3 gals. of water; while 3 lbs. of coal will produce 4 gals. of the liquid gas; 1 gal. of water, under 6½ atmospheres at 320 deg. Fahr.= 295 volumes of steam; 1 gal. liquid gas, under 6½ atmospheres at 50 deg. Fahr.= 983 volumes of gas.

The latent heat of water is 990 deg., and that of ammoniacal gas is 837 deg.

The boiling point of water is 212 deg., and of the liquefied gas 38.5 deg. below zero.

The boiling point of the ammoniacal solution, of 20 deg. Beaumé, is 140 deg.

The specific gravity of the gas is 0.59, air being unit; and of the liquefied gas 776, water being unit.

Water, thrown on a refrigerating worm or condenser, and of 70 deg. Fahr. at the start, can take up 20 deg. of heat and condense the gas still easily.

It will take about 40 gals. of water, at 70 deg., to liquefy 1 gal. ammoniacal gas.

The total loss of ammonia per annum should be taken at about 25 per cent.

Boxes of solution of ammonia, imported, contain 10 gals., *i. e.*, ⅔ water and ⅓ liquefied gas.

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The apparatus on the car worked perfectly well, stopping and starting with great facility, and without a jerk, and seemed to be under the perfect control of the driver—a carpenter by trade, who had been handling it only a few days. The total distance per trip travelled over, with about 15 or 20 persons in the car, was 3 miles, the time taken being about 20 min. —it was evident, however, that we could have travelled faster if required. By taking the mean of several trips, we ascertained, by the glass gauge, that we had consumed or *solutionized* 1.44 gals. per mile of the liquefied gas, contained in the inner or tubular vessel. The weak solution which had been put in the tank or outer vessel, at 15 deg. Beaumé, was found to weigh 23 deg. Beaumé when drawn out after returning to the depot; thus showing that it had been enriched 8 deg. by the absorption of the gas from the inner vessel.

We are informed by Dr. Lamm that it requires 5 gals. of the solution at 25 deg. Beaumé—which can be delivered here, he says, at 40 cents per gal.—to make 1 gal. of the liquefied gas; the latter would therefore cost $2 per gal.

We then determined the time required at the depot to liquefy the gas, and its approximate cost, by the machinery which he now uses, and which is considered still quite imperfect. We found that 73½ lbs. of bituminous coal liquefied, in 38 min., 18 gals. of gas from the solution of *aqua ammonia* at 23 deg. Beaumé. The well water used was at a temperature of 70 deg., and when taken from the condenser it showed 75 deg. The pressure of steam in the boiler during the distillation was 120 lbs. to the sq. in.; 37½ lbs. of coal consumed is at the rate of 116 lbs. per hour; and as 8 lbs. are equivalent to 1 horse-power, it follows that 14½ horse-power were used to obtain the 18 gals. of liquefied gas, or about 1¼ gal. per horse-power. The pressure gauge, meanwhile, showed 7½ atmospheres, or 110¼ lbs. to the sq. in. The water used for the distillation would be $\frac{40\text{ gals.} \times 38\text{ m.}}{18\text{ gallons.}} = 85$ gals., nearly, which multiplied by the 5 deg. added to its temperature, would give 425 deg. as the latent heat taken from the gas for every gallon of liquefied gas made.

We find that when coal is at $5.00 per ton, the cost of distilling aqua ammonia, at 23 deg. Beaumé, into 18 gals. of liquefied gas, with 7½ atmospheres, or 110¼ lbs. on the sq. in., and the temperature at 80 deg., is as follows:

| | |
|---|---|
| Coal, 73½ lbs., or .03675 tons, at $5 = . | $0.18375 |
| One engineer, at $5 per day, and 1 fireman, at $2 per day = $7 × .05277 days = ..... | 0.36939 |
| Original cost of machinery, say $5,000; of which 20 per cent. per annum, or $1,000 ÷ 365 = say $3 per day × .05277 = ..... | 0.15831 |
| Cost of liquefying 18 gals. of ammonia gas... ..... | 0.71145 |
| Hence 1 gal. of liquefied gas will cost.. | $0.039525 |

It is evident that this result, which has been obtained under the most adverse circumstances, such as the newness, roughness, and incomplete condition of the machinery employed, will be greatly reduced when machinery better adapted

to the object in view shall have been adopted and applied on a larger scale, say for 25 or more cars. Moreover, ammoniacal gas, as a motive power, is in its infancy, requiring time and continued use, like steam, to develop its great advantages; hence we feel no hesitation in saying that your invention is a success, and that it will ere long replace the use of mule power on all city railroads, and wherever steam cannot well be used. It has the advantage, also, of dispensing with the use of fire, and of having at all times its motive power ready for instant use.

We now submit the following estimate, based on our observations as already given, for running 25 cars nearly 95 miles, each, per day, this being about the longest distance travelled over at present by any one car.

In the preceding experiment, made on a small scale, 2 men, at $7 per day, obtained 341 gals. of liquefied ammonia, while they could have made 5 times that amount on a larger scale; hence twice the force could liquefy 10 times the amount, or 3,410 gals. per day, at a cost of $14. And we assume that if the distillation was performed by direct heat instead of steam, the fuel would be economized one-third; that is, 1392.6 lbs. of coal per day, less one-third, will give 928.4 lbs., which multiplied by 10 will be equal to 9.284 lbs., or 4.64 tons at $5. But the cost of the improved machinery would be increased from $5,000 to $15,000, the interest upon which may be taken at 8 per cent.; the wear and tear, repairs, oil, etc., at 12 per cent.; the interest on the capital ($864) invested in ammonia, at 8 per cent.; and the loss of ammonia per annum at 25 per cent. on said capital of $864; hence we find the following cost for making 3,410 gals. of liquefied ammonia for 25 cars running 2,368 miles per day, in all:

| | |
|---|---|
| Interest on $15,000, at 20 per cent. per day | $8 22 |
| Interest on $864, at 8 per cent. | 19 |
| Loss on ammonia, $864, at 25 per cent. | 60 |
| Coal, 4.64 tons, at $5. | 23 20 |
| Labor. | 14 00 |
| Total cost per day for 25 cars | $46 21 |
| One car per day will then cost | $1 85 |
| Hence 1 mile will cost | 0.019 |

or nearly 2 cents per mile.*

We have not availed ourselves of the economy claimed to be due to the use of ammoniacal gas in preference to steam, on account of its volume at 100 lbs. pressure being 3 times greater than that of steam under the like pressure. We have confined ourselves to the fact, that all liquids are simply the agents to transmit the heat or power of the coal consumed in the furnace, in the same manner as a belt or spur wheel does relative to animal power; hence we say that a pound of liquefied ammonia is equal to a pound of water, when both are subjected to the same force or heat; for, if the former, by volume, be 983, and expands 309 times, while that of steam be 303, and expands 1,397 times, the force of each will be nearly as 42 to 30, which is nearly as that of their densities—*i. e.*, 100 to 76. Therefore we would give the preference for running street cars to ammonia, which requires only the temperature of the atmosphere, even if it cost more than steam, as we would prefer to a spur wheel, a belt which makes but little noise, although it might slip occasionally.

The following objections, we are informed, are urged against the use of ammoniacal gas as a motive power:

1*st.* The danger of explosion.

2*d.* The deterioration of the iron by corrosion and brittleness due to the action of ammonia.

3*d.* The heat in the (outer) tank of weak solution of ammonia becoming too great as the distance travelled over increases.

These objections are, we consider, groundless. In the first place, only a pressure of from 3 to 10 atmospheres (45

* The following facts relate to one-horse cars on street railroads in New Orleans.

These roads are generally from 5 to 6 miles long, which is the length of the trip for one horse or mule, and he repeats this trip from 3 to 4 times per day; hence he travels from 15 to 20 miles per day, and the cars run from 80 to 110 miles each, according to length of road.

From 5 to 6 horses or mules—including sick and convalescents—are allowed per car, according to length and condition of the road. Horses generally cost fron $150 to $200 per head, and mules from $200 to $250. The mortality is about 5 per cent. per annum of the whole number used, and the sick and convalescents are about 10 per cent. The feed and attendance of the stock cost about 55 cents per day per head, depending on the market price of grain and fodder.

The total expenses per car, including repairs of tracks and cars, feed, pay-rolls, office-rent, insurance and contingent expenses, on a road say of 6 miles in length, and on which about 50 cars are kept running, amount to from $9.50 to $10.50 per day, of which about 50 per cent. belong exclusively to those items resulting directly or indirectly from the use of horses or mules.

As to the preference to be given to either kind of animal, it is still a mooted question; but it is probable that on long roads, where *speed* is required, horses have the advantage; their first cost is, moreover, cheaper. The objections to them are, that they require more care than mules, and do not last, under ordinary circumstances, quite as long.

to 150 lbs.) to the sq. in. will be ever used in liquefying ammonical gas as a motive power for car purposes; whereas, in the manufacture of *ice* a pressure of 16 atmospheres (240 lbs.) is frequently required, yet no accidents have happened in those manufactories which have been for several years in operation in America and Europe. Moreover, the ammoniacal gas is generated by the difference of temperature between 40 deg. below zero and about 80 deg. above (or that of the atmosphere); whereas, steam is generated by the heat of a furnace, at about 2,000 deg. Besides, the sensible heat of the steam is 340 deg. at the same pressure as the ammonia. These temperatures are irregular, being dependent entirely on the intelligence and faithfulness of the engineer and fireman. And, as it has been determined by reliable experiments that iron heated to 1,200 deg. above the ordinary temperature loses $\frac{2}{3}$ of its strength, the danger from steam will be apparent to all.

Relative to the second objection raised, that iron is corroded and rendered brittle by contact with ammonia, the result of observation shows, on the contrary, that it has the reverse effect, preserving it from rust; while, singular as it may appear, it rapidly corrodes copper.

With regard to the third objection, that the heat in the solution tank or condenser will become too great as the distance travelled over increases, thereby tending to produce an explosion. This danger need not be apprehended, for the heat in the condenser being dependent on the evaporation of the liquefied gas in the tubular boiler, cannot, under any circumstances, be of greater intensity than that which produced it; but even if possible, it would simply produce a back pressure equal to that of the tubular boiler pressure, and the engine must come to a rest.

We cannot conclude this report without expressing our acknowledgment for the patience you have shown and the courtesy you have extended to us during our investigation. We sincerely hope that fortune may follow in the wake of an invention destined to place your name high on the scroll of Fame, alongside of those which have illustrated the present century.

We remain yours most truly,

G. T. Beauregard,
*President N. O. and C. Railroad Co.*,
I. L. Crawcour,
John Roy,
*Engineer and Architect.*

To Dr. Emile Lamm,
*President Ammoniacal Propelling Co. of America.*

## STREET LOCOMOTION.

From "The Engineer."

A sudden terror has seized the public mind in reference to street tramways. Last year nothing was so popular. This year the car of Juggernaut would scarcely be more terrible to the inhabitants of Oxford street than the prospect of a tramway car trundling along from the Marble Arch to Holborn. New modes of locomotion always inspire alarm. Railways were once the dread of agriculturists, and the horror of territorial proprietors. That era having passed away, there next arose a cry of alarm when railway engineers proposed to invade London. Not even Printing-house square was safe, and the "Times" began to thunder against the projectors of intramural lines. Parliament took the matter resolutely in hand, and proceeded to sift the schemes so as to reduce the apprehended inconvenience to a minimum. Public feeling gradually quieted down, until roused once more in reference to the carrying of a railway to the Mansion-house. Railways are still pushing and feeling their way into the heart of London, and the public are readily availing themselves of the vast convenience thus afforded. Another mode of locomotion now presents itself—a sort of handmaid to the railway system, combining the easy traction of the rail with the primitive haulage of the horse. The authorities of the Board of Trade have looked with favor on this hybrid production, and tramways have become immensely popular since the disappearance of George Francis Train and the introduction of an improved rail. The eccen-

tric gentleman from New York did his best to make tramways a general abhorrence, and helped to delay their introduction by a few years. Something like the old feeling of antagonism has been revived of late, in consequence of numerous bold attempts to introduce tramways into the more crowded and fashionable parts of the metropolis. We are not saying that the opposition is altogether unreasonable, but we believe it emanates very largely from two portions of the community, the one being an important and the other an estimable class—namely, shopkeepers who have what are called "carriage customers," and the other class consisting of ladies who ride in the aforesaid carriages. The pleasurable excitement of "shopping" is threatened. The shopkeeper trembles for his profit, and the fair sex apprehend a serious interference with their indispensable amusement. Of course honorable members—particularly the metropolitan — cannot withstand this twofold influence. All the shopkeepers in Oxford street, except three infatuated beings, have petitioned against tramways. All the ladies in Mayfair and Belgravia would do the same if they had the opportunity. It is all very well for members of Parliament to write to the daily papers and say that the tires are wrenched off their carriage wheels, and that their horses get their legs sprained. The real fact is that every lady who rides in a carriage detests the tramway. In the nature of things it must be so. Not only does a tramway interfere with that perpetual zigzagging from one side of the street to the other, which is indispensable to the perfect pursuit of shopping, but there is something essentially and obtrusively democratic in a tramway. When a dainty pair of greys have to be pulled up at the behest of some insensate cabman, or stolid 'bus driver, the incident may be attributed to mere individual eccentricity or obtuseness. Under such circumstances Jeames himself may laugh compassionately, and her ladyship smile at the odd perverseness of the offender. But the tramway is an institution. It runs straight down the street, and when the driver puts his whistle to his mouth everybody must get out of the way. It is too palpable that the car clears all before it. If the driver wished to get out of the way he couldn't, and the vehicle sweeps on its course among the throng of equipages, as inexorable as fate. The whole affair is democratic, or what is worse, it is democracy possessing an exclusive power. It is a Yankee notion, and the West End shakes its head at the thing. It may do for Brixton or Whitechapel, but it may not be allowed in Oxford street, or even dreamed of in that paradise of peeresses—Regent street.

But what says Demos to all this? Demos is a creature who rides in "'buses," or occasionally sports a cab. He dives into underground railways, and patronizes penny boats. Demos, when a boy, rode in hackney coaches, those ponderous vehicles which disappeared so mysteriously about 30 years ago. We fancy there is a specimen at South Kensington, but cannot speak with certainty. When a youth Demos rode in a two-wheeled vehicle, the driver whereof was stuck on outside over the off-wheel in a manner marvellous to behold. It was a patent machine for breaking necks, and was gradually superseded by vehicles designed for the protection of the public. Finally there came the "growler," a sort of box on wheels, safe to break nobody's neck; and the "Hansom," a contrivance which has proved eminently popular and useful. In the midst of these mutations the London omnibus, like the penny steamboat, has adhered to its original type. Demos hates it. It is too conservative for him. Repeatedly has he sought to reform it, but he has never succeeded. It persecutes him unmercifully. It pitches him out backward when he tries to get in, plunges him into his neighbor's lap when he attempts to sit down, smashes his hat when he goes to the upper end, causes torture to his toes when he sits at the door, deafens him with its roar as long as he is inside, and finally flings him in the mud when he tries to get out. As for riding outside, many an acrobatic feat at a music-hall is less perilous, and a ride on the knife-board is like dancing on the edge of a precipice. We believe that the conductors of these singular vehicles are quite conscious of their defects, for only in that way can we account for the general civility which characterizes this class, in which respect they are decidedly superior to railway porters, and perfect angels when compared to those ferocious creatures who go about armed with nip-

pers, and with the dreadful words "ticket collector" embroidered on their collars. But to return to the omnibus. We believe it was invented in the latter part of the seventeenth century. It ought never to have lived in its present state to the latter part of the nineteenth century, taking the London omnibus as a specimen. Still it does live, to the torture of horse-flesh and the torment of Demos.

But Demos has of late enjoyed a ride in the tramway car. As he glided along, without jolt or rattle, and breathed the air of a spacious compartment, he relaxed his clenched teeth, stretched his weary legs, half wondered where he was, and at length exclaimed, "This is the ticket." The Board of Trade befriended him, and tramways were sanctioned by the score. But Aristos suddenly awoke, and there was thunder in St. Stephen's. A member of the Carlton, whose residence commands the junction of Edgeware road and the line to Oxford street, has led an onslaught against the ways of Outram, and Parliament has followed in his wake. The provisional orders of the Board of Trade are being upset, bills are being rejected, and tramways are told to keep their distance. There is great rejoicing among the directors, shareholders, officials, and servants of the London General Omnibus Company, Limited. Demos hangs his head and thinks dolefully of the inevitable "'bus." But there is hope even yet. In saying this, we don't mean merely that there is Mr. A. J. B. Beresford Hope, of Arklow House—Pandora's box has something in store for Demos. The other day the unfortunate Demos entered an ordinary omnibus, and to his infinite surprise it neither roared nor rattled. It seemed floating on a cloud. The silence was almost oppressive. He could positively hear himself speak, and the clatter of the horses' hoofs broke on his ear with an almost painful distinctness. While wondering at this strange phenomenon, he was startled out of his self-possession by an astounding crash, and a sensation as if an earthquake had suddenly laid hold of the omnibus. He was ready to rush past the conductor, when the mystery was explained. He had been riding on Val de Travers' asphalt, and had suddenly reverted to granite blocks. "All is not lost," thought Demos. Let asphalt be laid in the streets of London—such asphalt as more than one company can now produce, and possibly the need for tramways will either disappear or become very much modified. But the road omnibuses must be improved. The dead pull at starting must be superseded by the contrivance which gives the car the benefit of a start without a jerk. There must be a brake, so that the vehicle can be pulled up on the asphalt in something less than the eighth of a mile. The vehicle must be enlarged, and the passengers made comfortable. If the omnibus companies will agitate for asphalt, and will improve their vehicles, Demos will be less anxious for tramways. It is possible that tramways will ultimately triumph over all opposition; but the demand for them will be very much lessened if the public are allowed the benefit of asphalt in conjunction with proper vehicles. The street locomotion of London needs reform, and in some shape or other it must come.

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M. E. Becquerel has shown that the electric spark may be diversely and beautifully colored by being made to pass through saline solutions. If an electrical spark from an inductive apparatus be made to pass into the extremity of a platinum wire suspended over the surface of the solution of a salt, this spark will acquire special coloration according to the chemical composition of the solution traversed. The saline solutions are best concentrated, and the platinum wire positive. The experiment is readily performed in a glass tube. Salts of strontia will color the spark red; chloride of sodium, yellow; chloride of copper, bluish green, etc. The light from these sparks, analyzed by the spectroscope, furnishes a method for the determination of the nature of the salts contained in the solution.

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The Elevated Railway in this city is again in operation. A light dummy is used, which hauls two car-loads of passengers.

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Flocks of ostriches are being raised in South Australia for the sake of the feathers, the demand for which in Europe exceeds the supply.

# NEW SYSTEM OF MINE VENTILATION.*

From "The Engineering and Mining Journal."

The best methods of mine ventilation rest on the same principles as those of domestic ventilation. Whether we use the furnace, now almost and most fortunately out of use, or the *fan*, which is taking its place, to the great advantage of good ventilation, the action is the same, and a parallel case is not difficult to draw.

The great evils of our domestic ventilation are the prevailing evils of our mine ventilation also; but in addition to the vitiated air of respiration, condensation, combustion, etc., we have to contend with the spontaneous exhalation of carburetted hydrogen from the coal, in most of our deep mines; and in this constant and abundant generation of one of the most dangerous of explosive gases lies the chief difficulty and danger of our mining economy.

Still in the cure of the first great evil of our present system of ventilation, we find the remedy even for this; because here again the great laws of nature become available, or the provisions of nature suggest a remedy. Like heated air, carburetted hydrogen only needs the means of escape. Its tendency to fly upward is about equal to that of air heated to 500 deg. of temperature; consequently, if permitted to escape from the mines freely, this dangerous and now troublesome gas would not only become harmless, but might be made useful. Instead of a bad master, it might become a good servant.

But this consummation is impossible as long as our mines are ventilated on the principle of too many of our houses; and just here a parallel case may be drawn. We may compare a common chamber, or breast, or the face of a gangway, with the rooms of our dwellings, having only the flue of the stove or fire-place, perhaps but 4 or 5 ft. from the floor, for the escape both of the vitiated air of respiration and the products of combustion. Of course, above the point where the flue exists, the space is a receptacle for heated air, which, as long as it retains a certain degree of heat or rarefaction, will occupy this area with all the impurities of respiration and combustion common to such dwelling rooms, where there is no provision made for their exit by means of escape flues in the upper portion of the walls.

In a mining chamber, particularly when the coal bed is a "pitching" one (having a large angle of dip), there must always be a considerable space beyond the influence of the air currents; and this dead or stagnant place in all such chambers is always the highest portion. In this portion, corresponding to the upper part of a dwelling-room, the miner pursues his daily avocation; and here of necessity, in most of the chambers of a pitching coal-bed, he is compelled to work in foul air, and too frequently in an atmosphere of inflammable gas, simply because it is impossible, in most cases to make the air-currents pass along the face of the chamber in order to provide pure air to the miner and to carry off the gases that exhale from the coal.

To those familiar with our methods of ventilation, this proposition is plain, because we now carry the air currents from chamber to chamber, by means of cross-headings through the pillows which separate the chambers. Such cross-headings are always considerably in the rear of the "working face" of the chamber. Even if commenced close to the face, the face is constantly being advanced further and further from the cross-heading, through which the air-current passes, leaving the space in advance in a stagnant condition.

If the air is carried up on one side of a chamber and down the other, this same difficulty exists, unless there is a sufficient amount of "gob" to keep the middle of the chamber closed up near to the working face. This is scarcely ever the case; and the only other way in which the air-currents can be made to pass close to the face, is when the "rear" method is made use of. But this method is seldom available, and still more rarely desirable.

If we take the case of a gangway, or the main entry, with its parallel air-way, we find the same difficulty to exist, because here, as in the chamber, or the dwelling, there must always be a space in which stagnation exists, where the air-current cannot be made to pass, and where the

* A paper read, May 18, 1871, before the American Institute of Mining Engineers, at Wilkesbarre, Pa., by S. HARRIES DADDOW, of St. Clair, Pa.

gas will accumulate in any mine generating carburetted hydrogen.

The space in advance of the heading is always in this stagnant condition, unless air is supplied to the face by the small hand fan, which is often employed under such circumstances, unless the gases are abundant.

Thus our present system of ventilation is powerless to reach the vital point. It cannot pass the air-currents where pure air is most wanted. It is always behind, too low, or too far off from the miner; and is consequently compelled to work in a vitiated atmosphere, or worse, in an atmosphere of fiery elements. But here, as too often in our dwellings, we ignore a law of nature, and complain of the dangers to which we are compelled to submit, as if those dangers were also the result of inexorable, unchangeable laws.

If our analogy has been fairly made, natural ventilation will appear to be the same in the house as in the mine; but it appears to be more difficult to provide for the free escape of the gases of the mine than of the heated air of the dwelling. We have not, however, prepared this paper merely to present difficulties with which we are, unfortunately, too familiar; but confidently offer a method which we believe will prove a remedy as available as it is in every way desirable.

### ARTESIAN OR FLUE VENTILATION.

This innovation, which we will now try to present as briefly and concisely as possible, the writer claims as his invention, and presents it as such without hesitation, feeling confident of its practical utility both in regard to safety and economy.

The invention consists, first of a drilling machine, to be propelled by steam, compressed air, or water, which is light, strong, portable, and easily operated. This drilling machine is designed to make flues from each chambor to the return air course, or, in other words, *to drill holes in the place of cross-headings* for the escape of the gases and foul air from the chamber in front of the miner, just as the flues in the upper part of a room allow the heated air to escape naturally.

The author then exhibited a photograph representing the drilling machine in its smallest and lightest form ; but a double machine is designed to bore long flues, say from 300 to 500 ft.

The operation or cost of boring these flues from gangway to gangway, or from airway to airway, either on the dip of the coal-bed, or parallel to its strike (that is, at right angles to or parallel with the gangways), is a small matter compared with the cost of the frequent cross-headings now necessary, but dispensed with when the flues are substituted. Cross-heading is slow and costly; but the act of boring these flues through the coal is rapid and comparatively cheap. From 10 to 20 ft. per hour can be made by the machine drill with two men, while a yard per day is about the average advance made in the cross-heading. It may be argued that a flue 6 in. in diameter would be insufficient for the purpose designed ; but when we calculate the amount of air or gas, or both combined, that will pass through such a flue, we find even 4 in. ample for the ventilation of a single chamber.

These flues always lead from the chamber to the return air-course. They empty in the return; consequently, the suction of the fan is constantly exerted on the area of the flue, inducing rarefaction and a rapid current in the flue, and from the chamber. This flue is in the solid coal always in advance of the chamber. In fact, the chamber follows the flue; so that the escape of the gas and foul air is directly in front of the miner and away from him; while the natural lightness or ascensional tendency of the gas is thus made available, not only to make its own exit, but to carry away in its train other evils.

Every chamber is thus ventilated through an independent flue. The gas and vitiated air are drawn off directly from the locality in which they are generated. If the flue ascends, the gas would rush up of its own lightness, but when the flues are nearly horizontal, the suction or draw of the fan has the same effect on the foul air and gases. The fan, or some other mechanical means of drawing a current of air through the mines, is now always used, whether the beds are horizontal or inclining, consequently this power is always exerted to induce a current in the flues, just as the current is drawn through the heading at present. Of course, if the gas and foul air are drawn out of a chamber, the pure air will fill its place, because "nature abhors a

vacuum," and an abundance of pure air is provided in all the main gangways and in all the chambers, which are constantly open for its free entrance, without doors, or batteries or other diversions.

The flues thus convert the carburetted hydrogen from a dangerous gas to a useful element, while the miner may work fearlessly in his chamber, not only well rid of a lurking enemy, but in an abundance of pure air and *light*, because the naked, blazing lamp may be used where the dim light of the safety-lamp is frequently now all that the miner dare risk.

In addition to the difficulty, or, in fact, impossibility, of providing pure air to each miner, in the face of his chamber, by the cross-heading method, on account of the tendency of the gas to remain inside or above the headings, another serious evil exists in the mode of carrying the air-currents in large volumes, from chamber to chamber, through the mine. The gathering impurities go with the current, and pass from one miner to the other. Every opportunity is given to produce an explosive element, and nothing but an excess of pure air can prevent it in a gaseous mine. Consequently, 30,000 cubic ft. of pure air is necessary to ventilate, by the present method, where 5,000 cubic ft. is ample by the flue method, because it requires 10 times more pure air to render the gas innoxious than to supply the necessary air for the use of the workmen.

The simple use of the flue, always in advance of the work, thus provides perfect ventilation, and immunity from the dangers of explosive gases.

It may now be a question of practicability and relative economy between the present and the proposed methods.

### PRACTICABILITY.

The question of practicability lies simply in our ability to drill long holes in any direction through the coal; but we know, by actual experience, that a horizontal hole 300 ft. long can be drilled in *hard rock* by machinery less available than the drill now proposed. We know that coal can be drilled in any direction, or at any angle, at the rate of from 10 to 20 ft. per hour; and should the top or bottom rock be met by any undulation of the bed, the diamond drill employed will pass through it. The flues may be drilled from the upper levels downward to the lower levels, or from the lower levels upward to the upper levels; but, while the flue-method applies as well to the right angle blast or chambers, up the dip of the bed, we prefer, for many reasons, the *barrel-chambers*, which are driven at right angles to the dip, or parallel with the gangways. In such chambers the flues are bored horizontally, and with the course of the gangway or the "strike" of the bed.

### RELATIVE ECONOMY.

If we ignore entirely the many and great advantages secured in pure air and immunity from danger by the use of the artesian flues, and only compute the relative cost of boring flues and of driving cross-headings, we think no one would complain of unfairness.

We will take the simple case of a gangway, with its parallel air-way, and calculate that a cross-heading is driven between the two, a distance of 21 ft., at a cost of $5 per yard, or $35; while a single flue, 6 in. in diameter, could be bored in 2 hours, costing less than $5, if steam or compressed air is used, and less than $1 if water from the pumps is used as the motive power. In some of our gangways, where the gases are generated rapidly, a cross-heading is required every 20 ft.; but from 30 to 50 ft. may be more nearly the average distance from one cross-heading to another, either in gangway or chamber. We may calculate that every 1,000 yards of gangway or chamber will require from 100 to 150 yards of heading. By the flue method, the length of the flue is equal to the length of the chamber; consequently, in ventilating the chambers by this method, the length of the flue will be from 7 to 10 times the length of the cross-heading; while in the gangways the length of flue would be equal to the length of cross-heading, and no more. But 10 yards of flue can be drilled at much less cost than 1 yard of cross-heading can be driven. On the whole, we think the cost of the flues would only be about half the cost of cross-heading as usually practised; but we are willing to allow that the cost in this respect may be equal, including the cost of outfit, general maintenance, power, and operation. Still, should there be no actual economy in the relative cost of driving headings or of boring flues, we accomplish a desirable purpose with the one which cannot be

obtained by the other. We secure life, health, and safety, for which we now pay a *premium;* because we cannot expect a man to assume these risks for mere laborer's pay. Nor can we expect as much labor from a miner working in constant danger, if not in actual dread, as from one who feels secure and works without apprehension. Moreover, there is less professional skill required in the mere act of digging coal than experience, hardihood, and fearlessness in meeting and managing the dangers of our imperfect systems of mining and ventilation.

In the artesian flue system there is also a saving and convenience in dispensing with all doors, batteries, hand-fans, safety lamps, and fire bosses. The system is plain, simple, cheap, and applicable to all good systems of mining.

### FLUE PIPE EXTENSIONS.

When an air-way, incline, shute, or heading, is driven at points where the artesian flue cannot be bored, a system of sheet-iron pipes, made and put together on the principle of large stove-pipes, is used. Those pipes are fitted into an artesian drill-hole, extending from the gangway into the parallel air-way, and from thence the pipes are carried in any direction or angle, in one of the upper corners, or any place on top of such headings, etc., as are now supplied with air by the hand-fan. The suck of the fan on the mouth of the flue, and consequently on the flue-pipe, will draw the air up, or into such heading, by exhausting the gas and vitiated air from its face.

It is evident that an artesian flue cannot be bored so as to ventilate the main gangways, close up to the face. It is true that these holes may be bored quite close to the face, and much more frequently than cross-headings are now used, and would, therefore, carry the air much closer to the face than would otherwise be done; but, in order to secure a constant supply of pure air, the pipe-flues can be extended up to the face of the gangway, and the opposite end inserted in one of the artesian holes leading to the return air-way.

In connection with this system of artesian flue ventilation, and the drilling machinery which necessarily accompanies it, I have also constructed a suction fan on new principles, in order to get increased suction or drag in the return air-courses, and consequently in the flues, and for the further purpose of reducing the dimensions, or rather the diameter of the artesian flues as much as possible.

In order to create greater suction-power, I found it necessary to provide some means of preventing depression, and at the same time increasing the diameter of the side openings, which, under ordinary rules, would defeat the ends sought. But this desirable improvement I at length secured by using three fans in combination. The ordinary fan, as now used, is introduced, with a double cone around the shaft, the smaller ends on the line of the shaft or axis, and the bases joined together at the bases of the wings, thus diverting the air from the horizontal to the vertical line with the least possible friction or tendency to counter-action. But, in addition to this, I place a hub or extension at each side, and in these I place two fans, one on each side, with oblique vanes, on the principle of the anemometer, whose whole object and action is to suck the air in at either side. Of course, I can increase the size of the side openings in this fan to double the size possible on the old plan, because depression is simply impossible; and I thus obtain a plain, simple fan that will do double the work that can be accomplished by any other suction fan.

The system of ventilation herein proposed, however, is entirely independent of this new style of fan, which is not a necessary adjunct, but only a means of reducing the flues from 6 in. to 4 in. diameter. The common fan or the furnace can be used in connection with the flues just as they are used at present. No change in our modes of mining is actually necessary, though the band system is recommended as the most available, under all circumstances, both as to economy of mining and as to ventilation.

In this method the air invariably enters through the main gangways, passing up into the chambers, only as fast or in such volumes as can be carried off by the respective flues. Exhausted or worked-out chambers are closed, and the inside air-course, communicating from the lower to the upper level, is provided with a regulator to pass off the surplus air, and insure a sufficient quantity to each chamber.

# M. JANSENN'S BALLOON COMPASS.

From "Engineering."

The annexed particulars of an aeronautical compass, designed by the distinguished French astronomer, M. Jansenn, for determining the course and speed of balloons, are given in "Comptes Rendus" for February last, but have not, we believe, been noticed before by any English papers.

The balloon compass consists of a cylindrical metal case, 3½ to 4½ in. (10 to 12 centimetres) in diameter, and the same in height, fitted with a glass bottom, and open at the top. Two small arms on branches rise from the upper end of the case, and support between them a little metallic disc at a height of 10 to 12 in. (28 to 30 centimetres) above the glass bottom. This metal disc serves as an eye-piece, for which purpose it has a small hole a few millimetres in diameter, drilled in the line of axis of the cylinder. To this hole the eye is applied during observation.

Upon the glass bottom are engraved a number of concentric graduated circles, whose radii are so calculated that they may be visible through the eye-piece under angles of 1, 2, 3, and 10 deg.

The largest of these circles carries diametrical lines joining the points 0 and 180 deg., 90 and 270 deg., 45 and 225 deg., 135 and 315 deg. on its circumference. This is called the great circle.

The instrument is fitted with a suspensory apparatus upon Cardan's principle, so as to insure the verticality of the axis of the cylinder during observation. A compass needle is fitted to the glass bottom, a little eccentrically, so as to leave the vision unimpeded in the line of axis. This is also provided with a small graduated circle, of which the needle's pivot is the centre, and which is so divided that the cord of 180 deg. may be parallel to the line 0—180 deg. of the great circle.

This compass will show both the course and rate of speed of a balloon.

The instrument is hung clear of the car by means of hooks inserted in the balloon's equator. It is adjusted by bringing the needle over the meridian line of the compass circle, *i. e.*, over chord of 180 deg. Looking down at the earth's surface through the eye-piece, we wait until some suitable object or portion of an object appears in line of axis. We then count the seconds which elapse before some object clears the great circle (the eye being close to the eye-hole all the while), and note the division of the circle at which it makes its transit. The meridian line of the compass, and consequently the needle when the instrument is in adjustment, being parallel to the diametrical line 0—180 deg. of the great circle, a line drawn from point of transit to centre of great circle will make with line 0—180 deg. an angle equal to the bearing of the balloon's course from magnetic meridian. This angle must be corrected for declination to give true course. When the balloon is disturbed by rapid rotary whirls, as sometimes happens, allowance must be made for the effects. The axis of the compass, in place of pursuing a course parallel to the line followed by the centre of the balloon, describes a cycloidal curve, and the course indicated is a tangent to the curve at the point of transit. But, it must be remembered, these tangential lines form equal angles, but of opposite signs, with the true course in each pair of points separated by a half rotation of the balloon. A mean of the apparent angles thus obtained should therefore be taken.

To measure the speed, we have to note the time apparently occupied by a point on the earth's surface in traversing a radius of the great circle. In reality it is the time occupied by the balloon in describing a conic projection of such radius upon the earth's surface. This time bears the same proportion to the altitude of the balloon above the earth's surface as the radius of the great circle bears to the height of the instrument. Now the radius of the great circle being calculated so as to be seen through the eye-piece under an angle of 10 deg., it follows that this proportion is as the tangent of 10 deg. to radius, *i. e.*, as 0.176 to 1. If, therefore, the time observed be 18.4 sec., and the altitude of the balloon 2,200 metres, the speed will equal $2{,}200 \times \frac{0.176}{18.4}$, or 21 metres per sec., which is 76 kilometres (about 47 English miles per hour).

This, it may be observed, was the speed of the "Volta" during M. Jansenn's famous trip from Paris en route to join the "Eclipse" expedition. It will thus be seen, M. Jansenn writes, that the calculations required are of a very simple character. The necessity of performing them in the balloon may be obviated by having a small table prepared, so as to show the results on inspection.

The course and rate of speed can thus be obtained by a single observation, the only additional data required being the altitude of the balloon, which is taken by the barometer. Here, too, much time and trouble may be spared by using a pocket table with the corrections suited to the meteorological elements of the day of observation. In place of the barometer, small grenades on the concussion principle may be employed. One of these dropped from the balloon will ignite on striking the ground, and the number of seconds betwixt the flash and the arrival of the report will give a sufficiently clear approximation to the altitude.

The compass may be employed to ascertain the balloon's course in another way. The branches before referred to are furnished with small sight vanes. With the aid of the latter we may determine the azimuth of distant objects. By thus observing a distant object over which the balloon has passed, we can ascertain the magnetic bearing of the balloon's course. M. Jansenn adds that perfect repose is not essential to the employment of the instrument. Moments of exceptional disturbance must be avoided, but under ordinary circumstances it will be sufficient to have the car well balanced, the aeronauts keeping in their places and guarding against any movements calculated to disturb the "trim" of the machine. He found no difficulty in using an ordinary telescope in the "Volta" whenever required.

M. Jansenn promises further information upon the subject of instruments for the determination of the course and speed of balloons at night or in foggy weather. His observations have not, we believe, as yet appeared.

## THE HANNIBAL BRIDGE.

From "The Railroad Gazette."

This combined railroad and highway bridge over the Mississippi river, at Hannibal, Mo., has just been completed, the seventh structure that spans the great river, below Dubuque. The work has been completed under the administration of the "Hannibal Bridge Company," formed by the consolidation of two companies—the "Pike County Bridge Company," incorporated in Illinois in March, 1867, and organized June 4, 1869, with Alexander Starne, President and Ozias M. Hatch, Secretary and Treasurer; and the "Hannibal Bridge Company"—incorporated in Missouri, May 24, 1869. In December, 1869, the consolidation was effected under the present title of the company; Mr. John T. K. Hayward, of Hannibal, was elected President and Ozias M. Hatch, of Springfield, Ill., Secretary. The present organization of the company is: Alexander M. White, President, Isaac M. Knox, Secretary and Treasurer; Warren Colburn, Consulting Engineer; Col. E. D. Mason, Chief Engineer, with E. L. Corthell and Eliot Clarke as assistants.

On the 27th of June, 1870, Col. Mason, with his corps, commenced the preliminary surveys, making minute examinations of the river bed and the underlying strata at various possible crossing places. By means of sounding rods, he bored to a depth at some points of 110 ft. below low-water mark. The direction and velocity of the current was carefully noted by the use of floats, and the line of the bridge was located at right angles to it. A base-line of 1.620 ft. was accurately measured, and its extremities indicated by raised monuments. From this line as a base all the positions for the piers were located by triangulation, and afterwards tested by actual measurement with a steel wire, proving their accuracy.

On the 29th of July, 1870, a contract for both substructure and superstructure of the bridge proper, between and including the abutments on each side of the river, was entered into with the Detroit Bridge and Iron Works. The plans for the substructure had been previously prepared by Col. Ed. D. Mason, the Chie

Engineer. The Bridge Company adopted the plans of superstructure as designed by Willard S. Pope, Engineer of the Detroit Bridge and Iron Works. The agreed price for the whole was $185,000. By the terms of the contract the work was to be completed ready for use within one year. The time was very short—much less than that before given for any similar work, but the contractors have met the requirement.

This bridge belongs to the general class of "low bridges," placed but a short distance above the high-water mark and furnished with a draw span over the channel to permit the passage of steamers and river craft generally. The comparative advantage of high and low bridges over navigable streams is a question of money only. The high bridge, offering practically no obstruction to river traffic at any stage of the water, and requiring no attention on the part of its keepers in distinction from the constant service required at a draw, presents, in this respect, points of superiority over the low bridge. But the increased height of the piers, and the length of approaches necessary to attain the elevation, adding very largely to the cost of the structure, led in this case to the adoption of the low bridge and draw as the most economical structure. Confirmations of this opinion are furnished by the bridges at Quincy, Burlington and Kansas City, as well as by the plan adopted for the bridge to be built at St. Joseph. At St. Charles, St. Louis and Leavenworth high bridges have been favored and adopted for reasons other than those of economy.

The bridge under consideration is nearly identical in form with those at Burlington and Quincy, differing only in some of the mechanical details. One of the more important distinctive features is the form of the struts or posts used. These are composed of two parallel channel or I beams secured a short distance apart by diagonal bracing of wrought iron straps, forming an open work strut, the interior of which is accessible to the brush of the painter, whose attention is frequently needed to prevent rust—the destroying enemy of iron structures. The free ventilation afforded prevents the condensation of moisture in the interior and consequent rust, a salient feature of the tube-like "Phœnix column." In weight for the same strength there is little difference, while the facility of construction is slightly in favor of the new form. The form of the chord link differs from that used at Quincy in being formed of bars and eyes, instead of the experimental form built there of elongated links drawn out from a flattened ring. The upper chord shows an important modification. Instead of being of continuous size throughout, the ends of each section are considerably enlarged and the abutting faces planed exactly perpendicular to the axes of the beams, thus adding much to their stiffness and allowing the omission of the short diagonal lateral braces. The increased size of the chord at the joints permits the passage of the tie road to an interior fastening, instead of being secured to a *lug* on the outside.

The foundations, upon which depends the permanency of the work, in all cases—excepting that of the west abutment, which is built up from the rock—are supported upon pile bases. The piles in piers 2 and 3 were driven to the rock, and at the other piers they were driven until a sufficient resistance was obtained. Upon the piles, cut off at a level with the bottom, was placed a grillage of heavy timber, forming the foundation for a floating caisson. This caisson was sunk to its position as the masonry part of the pier was added to its weight, the sides being kept above water until the mass was fairly settled upon the pile heads. This method, when admissible, furnishes the most economical, as well as expeditious, means of placing the masonry upon foundations under water. To prevent scour, the spaces between the piles themselves, and the space between the bottom of the grillage and river bed, are filled with riprap, and a bank is formed, around the outside, of the same useful material. The serviceable nature of riprap in resisting scour is well known, and the engineer in charge of this work has been led by his experience to place great confidence in its ability to withstand the currents of the Mississippi.

At the west abutment the rock bed of the river was found but a short distance below the surface, and the masonry was placed directly upon it. The rock, a variety of blue soapstone, was excavated in steps, to receive the wing walls. This abutment contains 372 yards of masonry.

The following table shows the time occupied in the construction of each pier, and the depth of water at the several points at the time of the sinking of the respective piers.

Pier No. 2, being situated in the current of the river, required protection piles as a guard against drift. All piles were driven to the rock bed, thus demonstrating that piles could be used for the sub-foundations, by properly protecting them from scour, with riprap placed between and around them by divers. The average number of blows to the piles in the foundations was 112, from a hammer weighing 2,700 lbs., falling 25 ft. at the last blow. A floating caisson, formed of grillage of 12-in. sq. oak and elm timbers, well bolted together, and carrying planked sides to above the water line, was guided in its descent by cables, which were secured to a water deadener, and side anchors, until it was settled upon the heads of the cut piles, at a depth of 18 ft. below the water line of that date. The stone-work consists of 496 cubic yards of masonry.

| Piers. | Work Commenced. | Completed. | Depth of Water. |
|---|---|---|---|
| | | | Ft. |
| Pier No. 1 (West abutment) | Oct. 10, 1870. | May 27, 1871. | 0 |
| " No. 2 | Oct. 10, 1870. | Nov. 13, 1870. | 18 |
| " No. 3 (pivot pier) | ..... | May 27, 1871. | 31 |
| " No. 4 | Dec. 13, 1870. | March 8, 1871. | 22½ |
| " No. 5 | Jan. 8, 1871. | Feb. 4, 1871. | 14 |
| " No. 6 | Dec. 6, 1870. | March 5, 1871. | 10 |
| " No. 7 | Nov. 22, 1870. | Jan. 31, 1871. | 10 |
| " No. 8 | March 27, 1871. | April 5, 1871. | 12 |
| " No. 9 (East abutment) | Feb. 15, 1871. | April 22, 1871. | 5 |

The piles of pier No. 3, the pivot pier, were driven to the rock, and, after dredging out the sand to a sufficient depth, were protected by riprapping. A sunken crib was used as a water deadener. Much trouble was experienced from sand banks forming over the heads of the cut piles, requiring the use of divers, dredges, and, finally, a water jet thrown from a steam fire-engine.

The dipping of the rock bed carried it beyond the reach of the piles for piers 4, 5, 6, 7, 8 and 9, and these piles were driven in the sand until a sufficient amount of resistance was obtained; the permanency of the sand being secured by that indispensable material, riprap.

At piers 8 and 9 the sand had to be dredged out to allow the wooden grillage to be placed at a sufficient depth below low-water mark—the condition of durability of the wood-work being that it must *always* be covered by water, in order to exclude the air. In this situation it is practically indestructible.

The draw rests are sunk on islands of riprap, and consist of strongly braced cribs presenting a sloping edge to the current. Their interior is filled with riprap to the top.

The bridge is approached from the west by a long curve, completing a right angle with the river and passing through a tunnel of 302 ft. in length, cut through what is called lithographic limestone. The excavation was made at the east heading with Burleigh drills and powder and nitro-glycerine blasts. At the west end, by hand-work alone, a heading of full width, and some 9 ft. in depth, was driven through the top of the heading, being on a line with the roof of the tunnel; the bottom was cut out afterwards. Its dimensions, after being lined throughout with brick, are 302 ft. long, 20 ft. high, and 18 ft. wide.

Both entrances are ornamented with handsome cut-stone faces.

The approach at the east bank of the river is over 1¾ miles of embankment, across the river bottom land, broken at proper intervals by paved culverts and roadways, and protected by revetment walls at points subject to wash.

The following analysis has been made of the two qualities of limestone from the Hannibal quarries used in the foundations.

The figures in this analysis give evidence of the comparative superiority of this limestone, as claimed by the engineer, in that it has comparatively small quantities of alumina a small capacity of ab-

sorption and consequent density, and very great specific gravity.

| Constituent Parts. | Hannibal Brown Limestone, upper layer. | Hannibal White or Blue Limestone, lower layer. |
|---|---|---|
| Insoluble in acids | 1 295 | 0.390 |
| Iron | 0.640 | 0.453 |
| Alumina | 0 550 | 0 852 |
| Carbonate of Lime | 80 805 | 93.365 |
| " Magnesia | 14.650 | 2.320 |
| Alkalies | 1.060 | 1.120 |
| Water | 1.000 | 0.500 |
| Total | 100.000 | 99.500 |
| Specific gravity | 2 563 | 2.585 |
| Weight per cubic feet | 159.73 | 161.00 |

As stone from the same quarry has already stood long and severe tests in some of the older buildings at Hannibal, there is no necessity for fine argument upon its chemical composition, and no reasonable doubt can be entertained of its being all that is required for the purpose.

In the foundations there were used 650,000 ft. (board measure) of square timber and plank, 709 piles, and 6,270 cubic yards of riprap. There are 4,519 cubic yards of masonry in the piers, distributed as follows, numbering the piers from the west bank: No. 1, 372; No. 2, 496; No. 3, 1,340; No. 4, 514; No. 5, 400; No. 6, 326; No. 7, 333; No. 8, 310; No. 9, 430.

In the superstructure are 1,000 tons of iron, and 280,000 ft., board measure, of timber and planks in flooring.

The cost of the bridge proper was $485,000, the tunnel on the west bank $36,000, the west approach $56,000, and the east approach $71,500—making the total cost of the structure $648,500.

### SUPERSTRUCTURE.

The spans are arranged as follows: Beginning at the west bank of the river, one fixed span, 250 ft. long; one pivot draw-span, 362 ft. long, leaving, when opened, a passage way for steamboats 160 ft. clear width on each side of the draw pier; one fixed span, 250 ft. long; and four fixed spans 180 ft. long each. The measurements of length are taken in each case, from centre to centre of masonry, and then the total length of the bridge, from centre to centre of bridge-seats of abutments is 1,582 ft.

The superstructure is of the general style known as the quadrangular truss, with horizontal and parallel chords, vertical struts—except those at the ends, which are inclined over one panel—and inclined ties. In the fixed spans the upper chords and the joint pieces, etc., are of cast iron, and all the remaining parts are of wrought iron. The draw-span is of wrought iron throughout, except joint pieces and wheels, truck, etc., of the turn-table, the flooring placed at the bottom of the bridge, and is uniformly 18 ft. wide.

The general characteristics of the different lengths of spans are as follows:

| | In draw-span 362 ft. long. | In one fixed span 250 ft. long. | In one fixed span 180 ft. long. |
|---|---|---|---|
| Depth of truss between centre of chords { at pivot pier | 34 ft. | | |
| Depth of truss between centre of chords { at ends | 26 " | 25 ft. | 23 ft. |
| Width between centre of chords | 20 " | 19.6 ft. | 19.6 ft. |
| Number and length of panels { 2 centre panels | 11.2 ft. | | |
| Number and length of panels { 26 ordinary panels | 12.11 ft. | 19 pan 13 ft. | 13 pan 13.7 ft. |
| Weight of cast iron | 65 tons. | 50 tons. | 25 tons. |
| Weight of wrought iron | 235 " | 125 tons. | 63 tons. |
| Oak flooring | 31 M. | 22 M. | 16 M. |
| Pine flooring | 31 " | 22 M. | 16 M. |

### STRENGTH OF BRIDGE.

The main parts of the structure are so proportioned that a moving or live load of 2,500 lbs. per lineal ft. of bridge, in addition to the weight of the structure itself, and the flooring thereon (or the dead load), shall bring on no part a greater strain than ⅓ of its ultimate capacity. This general rule was applied to those parts which receive their assumed load only when the whole or a considerable part of the span may be occupied by a train of the assumed maximum weight. Those parts, such as single-panel systems, which receive their full load each time an engine may cross the bridge, are utilized to the extent of

$\frac{1}{6}$ their ultimate capacity, while the bolts supporting the floor system can never receive a load exceeding $\frac{1}{4}$ their strength. The actual relation, therefore, between the calculated final strength of the structure and its assumed working duty is shown to be as follows, taking the 250-ft. span as an instance :

| | |
|---|---|
| Dead weight of span | 240 tons. |
| Live load of span | 310 " |
| Total weight and load | 550 " |
| Ultimate strength of bridge (factor of safety 5) | 2750 " |

The dead weight, of course, remains constant under all conditions ; therefore, of the gross strength ot the bridge 2,510 tons is applicable to the support of the live load, which is in the ratio of more than 8 to 1.

In other words, when the bridge is fully loaded with its assumed maximum of 2,500 lbs. per lineal ft., it will still be capable of sustaining before fracture the imposition of an additional load of 2,200 tons.

This large excess of strength is practically still further increased, from the fact that the assumed live load of 2,500 lbs. per lineal ft. can never be actually reached, even though the bridge were loaded from end to end with engines, and from the additional fact that the actual strength of the iron used is considerably in excess of that demanded by the specifications. This combination of circumstances and facts gives a reasonable assurance of abundant strength.

### CONSTRUCTION.

The top chords of the fixed spans are of cast iron, octagonal in exterior section and circular within. In the 250 ft. spans these chord pieces are 14 in. in diameter between the opposite exterior faces. The thickness of metal varies with the varying strains.

They are cast in lengths of one panel, the joint occurring immediately over the head of the vertical posts to which each chord-piece is bolted. The ends are widened for the reception of the post-head, the main and counter tie-rods, and the upper lateral strut and ties, all of which assemble at that point. Thus while in the 250 ft. spans the chord-pieces are 14 in. wide throughout their interior length, they widen at their ends to 24 in. This increase of width at the joints increases largely the lateral stiffness of the bridge. Where the chord-pieces abut against each other, their faces are turned off in a lathe square and true to their axes, and they are connected with each other by a tenon and socket joint.

Immediately under the joint is placed the post or vertical strut, the seat for which, on the under side of the chord, is planed to a true bearing. The post-head is of cast iron, machine-finished to correspond with its seat. The posts themselves are of rolled channel or I beams, arranged in pairs, connected together by a system of wrought-iron riveted lattice-work. The two beams thus united form a hollow, open post, rectangular in section. They range from 10 in. to 24 in. wide, varying in depth with the depth of the constituent beams. The beams extend from the post-head to a point 6 in. below the centre of the main coupling-pin passing through their foot ; the pin-seat in the post being reinforced by a cast-iron plate or washer riveted to the web of the beams. The beams of which the posts are built vary in dimensions in accordance with their duty, from channel beams of 6 in. depth weighing 10 lbs. per ft., to I beams of 15 in. depth weighing 66$\frac{2}{3}$ lbs. per ft.

It will be seen from this description that the posts are continuous and without transverse joint from end to end ; and, furthermore, that all faces or sides of the iron of which they are built are at all times open to inspection and accessible to the paint-brush. It is considered that this is a material improvement over the closed cylindrical wrought-iron posts that are often used in similar places. Such a construction generally involves the necessity of an independent cast-iron foot or base, thus placing a full transverse joint across the body of the post; and, furthermore, the inside of these posts can never be reached either for inspection or protection, after they are once in place.

The main and counter ties are placed in piers connected at the lower end with the bottom chords and posts by a pin, and at the upper end passing through the top chord immediately over the post-head and secured in their position by nut and screw. They run diagonally, reaching from the pin at the foot of one post to the head of the second post beyond, their vertical rise being the depth of the truss and their horizontal reach being the length of 2

panels. They are of rolled iron, square in section, their lower part being formed into a loop, which is drilled to fit the pin; and their upper end being shaped into a cylindrical form on which the screw is cut. The end forming the screw is enlarged so that the sectional area of metal at the bottom of the screw thread is in each case larger than the sectional area of any part of the body of the bar. The nuts are faced to a true and perfect bearing on their respective seats.

The lower chords are of square iron of the length of one panel, formed with a drilled loop at each end, through which the pins pass. They vary in size and number in each panel, according to the duty demanded by their position. In their manufacture the most scrupulous care was taken to have them all of exactly uniform length between centres of pin-bearings.

The upper lateral struts are of rolled channel beams 6 in. deep, weighing 10 lbs. per ft., placed in pairs, between the top chords at their joints over the post-heads. The lateral ties above and below are of round iron bars 1¼ in. in diameter.

The floor-beams consist of rolled I beams 15 in. deep, weighing 50 lbs. per ft. suspended in pairs from the pins at foot of posts. The bolts suspending the floor-beams and the coupling-pins are forged bodily from selected scrap, under heavy hammers, and afterwards machine-finished for their respective positions.

The above description of the parts of the fixed spans applies equally to the draw-span, except that in that span the chords are necessarily different, as is demanded by the varying nature of the strains, which change from compressive to tensile, or the reverse, as the draw is open or shut.

They are built of channel beams 12 in. deep, 33½ lbs. per ft., placed in pairs, and connected together with plate iron, thus making generally a trough or hollow box of 3 sides, 24 in. wide, and about 12 in. deep. The joints, which are carefully broken, are spliced with appropriate cover-plates, and the whole thoroughly riveted together.

The top and bottom chords are substantially similar, varying in dimensions, etc., only with the varying duty. The turn-table on which the draw-span revolves consists of a rectangular hollow girder or drum, 18 in. wide, and 4½ ft. deep, curved to a circle, with an exterior diameter of 37½ ft. The sides of this drum are of plate iron, and the top and bottom are of cast iron, and are separated by 30 cast-iron stiffners, or diaphragms, carefully fitted to which, and to the top and bottom segments, the side plates are thoroughly riveted. This circular drum revolves upon 48 heavy cast-iron wheels or rollers, placed under it, and they in their turn rest upon a cast-iron track bolted to the masonry of the pier. These wheels are connected with each other and with the centre step by bands and radial axles. The wheels and the upper and lower track bearings are chilled to great hardness to resist wear. From the bottom of the revolving drum pass truss-rods, the upper ends of which bear upon a heavy central cast washer, at the bottom of which is the pivot-pin, of wrought iron, 8 in. in diameter. This pivot-pin turns upon a gun-metal bearing in the top of a central conical block of cast iron, which is fastened to the masonry.

The adjustment of the load between the exterior wheels and the central pivot is made by means of the truss-rods above mentioned.

The ends of the draw are secured in their position on the piers by means of a system of cams, so arranged with screw and connecting rods as, when being run down, to absolutely lift the ends of the bridge. This device is essential, as otherwise, when a train might be entering upon one end of the draw, one wing being thus loaded and the other wing being empty, the unloaded end would rise from its bearings, and thus serious and complex strains be induced upon parts of the structure.

But by absolutely and sufficiently lifting the ends of the bridge upon solid bearings this difficulty is entirely avoided, and the structure can thus be treated legitimately and correctly as a beam resting upon 3 points of support, and the complexity of the problem of strains be immensely simplified.

The bridge is turned and the machinery of the end cams operated by a double engine of about 20-horse power(nominal) placed on an iron platform laid for the purpose on beams supported by the main posts over the turn-table. This platform or floor is placed at a sufficient height

above the lower chords to allow the passage of trains beneath it.

QUALITY OF MATERIALS.

Samples of all the wrought-iron bars used in the bridge were tested to their ultimate capacity before acceptance.

The tensile strength ranged from 55,000 to 65,000 lbs. per sq. in. of sectional area, and the lowest limit of permanent set was about 2,500 lbs. per sq. in.

The stretch before final rupture was about 20 per cent. of the length of the original bar, and the diminution of area proportional therewith.

The cast iron was from a mixture of 75 per cent. of No. 1 Lake Superior charcoal pig, with 25 per cent of Scotch pig of the brand known as "Calder iron."

Test pieces were cast 2 in. deep, 1 in. wide, and 40 in. long. These were placed edgewise upon bearings 36 in. apart, and were called upon to sustain the transverse strain from a load of 2,800 lbs. placed at the centre.

All the test pieces showed higher capacity. The hollow chord pieces were drilled and accurately callipered for thickness.

After manufacture and before being placed in the bridge, each piece of bar iron was placed in the testing machine, and subjected to an actual tensile strain of 15,000 lbs. per sq. in. of sectional area, and while under such actual strain, received several sharp blows from a hammer. Any imperfection or weakness detected by this treatment condemned the bar. Of the many hundreds of bars thus treated, only 2 exhibited any sign of failure, and in both these instances the defect was in the original bar, and not in any part that had been worked at the shops. As soon as finished, and before leaving the works, every piece received 1 coat of paint, composed of oxide of iron and oil.

All the iron work was done at the shops of the Detroit Bridge and Iron Works, at Detroit, and having been fitted together there, each piece was marked, so that when brought to the place of final erection every part went to its place with perfect accuracy.

FLOORING.

Upon the iron floor-beams are laid pine stringers, placed longitudinally. Under each rail in the track are 2 pieces, 7x16 in., and in addition thereto are 4 parallel pieces, 6x14 in. All these are laid upon small oak bolsters, which rest upon the iron beam. On the top of the stringers are oak ties, 6x8 in., spaced about 20 in. apart, between centres, reaching entirely across the bridge. A double course of 2-in. oak flooring-plank forms the roadway, the track for engines and cars being of the pattern known as street rail, the top of which is flush with the top of the oak flooring. A substantial oak wheel-guard, and a strong neat hand-rail form the side protection.

PAINTING.

The entire superstructure received, after erection, 2 thorough coats of paint. For the main trusses the paint was of strictly pure white lead, tinted to a light drab, while the floor-beams, track-stringers, and hand-rail were covered with iron paint of a dark brown shade.

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A LATE number of Poggendorff's "Annalen" contains an account of an experiment made by E. Budde, to ascertain whether a Leindenfrost's drop with water could be produced at a less temperature than 100 Cent. The experiment was made by letting a drop of water fall upon a hot plate covered by a partially exhausted receiver, and it was found that the drop assumed the spheroidal condition at a temperature of 85 Cent., confirming the doctrine that the force which supports the drop obeys the laws of the pressure of vapors. The star shape assumed by the drop, Berger has explained to be a phenomenon of vibration. If the drop is large it behaves like other vibrating bodies, and divides into aliquot parts, forming nodes or loops.

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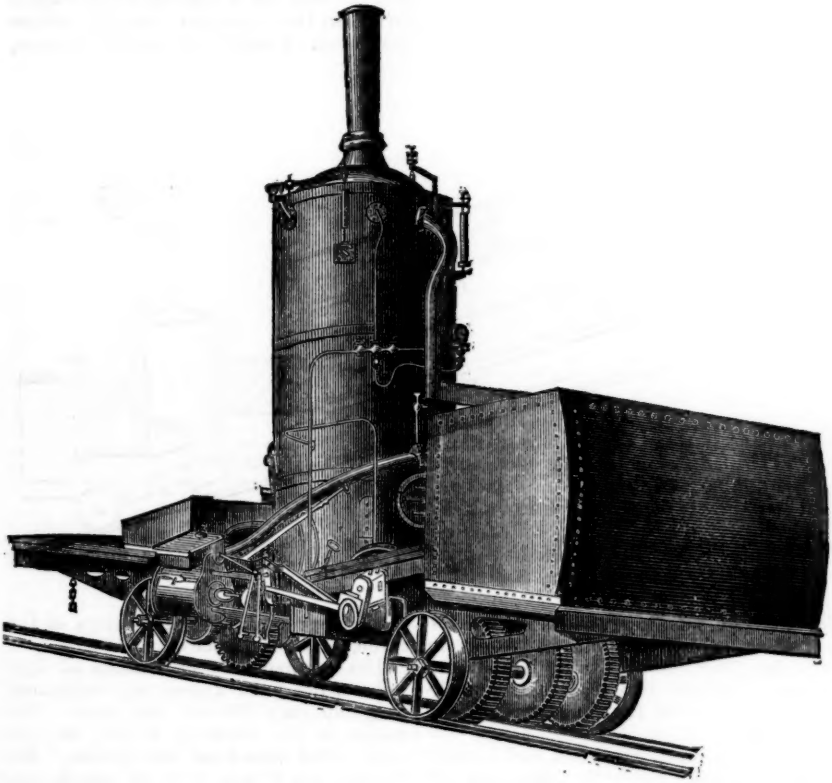
THE state of the Belgian iron trade continues favorable. Almost all descriptions of iron are in good demand, especially plates; considerable quantities of these latter have been sent to Germany. A contract for 2,000 tons of rails for the North-West Austrian Railway has been divided between the Thy-le-Château, the Couillet, the Monceau, and the Sclessin Works.

## THE RIGI RAILWAY.

The "Organfur die Forschritte Eisenbahnwesens" gives the following particulars of the railway that has been lately opened (23d May) on the Rigi. The line commences at Vitznan on the Lake of Lucerne, and terminates for the present at the baths of Mont Rigi, situated at 4,000 ft. above the level of the sea, but will be ultimately extended to the top of the mountain. This bold undertaking is chiefly due to Messrs. Naef, Zchoke, and Riggemback, who, previous to commencing the works, made a series of experiments at Olten for the purpose of testing the various systems of mountain engines, amongst which may be mentioned that of Mr. Fell, which is adopted on the Mont Cenis tunnel railway, the Welti engine,



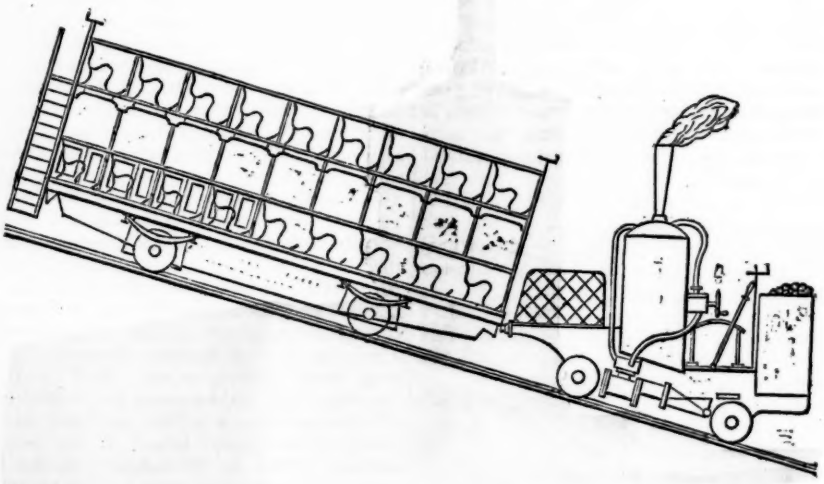
etc. The engine of Mr. Riggembach was found to be the best suited for the purpose, and was therefore adopted.

The line commences at a turn-table 12 metres in diameter, situated at a short distance from the lake, and, ascending with a gradient of 6½ per cent., reaches the village of Vitznan. Here the gradient changes to 25 per cent., which is retained (with the exception of some short lengths of 22 per cent.) to the summit. The curves are numerous and are principally of 180 metres radius. At 1,000 ft. above the level of the sea the line passes through a tunnel in the rock 67½ metres in length, and immediately crosses a ravine 30 metres in depth by a viaduct, consisting of 3 spans of 24½ metres each.

The piers for supporting the girders are of iron work, strongly braced together and firmly fixed in foundations of granite; these piers are 10.80 and 8.10 metres in height respectively. The girders are placed 2.10 metres apart, and the distance between the parapets 4.20 metres. To add to the difficulty of the undertaking, the viaduct is situated on a curve of 180 metres radius, and with a gradient of 25 per cent. On the viaduct the rails and rack are fixed to longitudinal sleepers.

About half way up the mountain, near the Freibergen station, the line is provided with a siding to allow the up and down trains to pass each other, and at the lower end of the line there are also sidings communicating with the engine sheds. There are 3 watering stations on the line, supplied by natural pressure obtained from the mountain springs.

Several deep cuttings through the rock, and high retaining walls in various places on the line, were found necessary to be made, and as, from the steepness of the locality where the line had to be made, it was found impossible to employ carts for the transport of earth, sledges were used. A sufficient quantity of stone,



fortunately, was near at hand for the construction of the various works in masonry, and had only to be hewed into shape and rolled into place. The workmen employed on this line were chiefly Italians.

With such steep gradients, and on such rough ground, which in places was almost inaccessible, it may be easily supposed that the setting out of the line was a task of no slight difficulty. On leaving the lake the railway takes a south-westerly direction towards the rocks of Vitznan, and on leaving the tunnel the course of the line is north-west, and on this part of the line the passengers will not fail to enjoy the magnificent panorama of the lake at their feet, with the Alps in the back-ground, with the valleys of Lucerne, Alpnach, Buochs, and Weggi.

The permanent way consists of light rails, of the form known as "vignoles," weighing only 33 lbs. per yard. The gauge is the ordinary 4 ft. 8½ in., the rails being fished at the joints. The sleepers are of oak, 8 ft. in length, and placed 2 ft. 6 in. apart. The end of the sleepers are bolted to longitudinal timbers, thus forming a strong framework; besides this every fourth sleeper is firmly fixed to the rock by masonry, so as to prevent any chances of the line slipping in a longitudinal direction. In the centre of the line between these rails is a rack, fixed to the sleepers by angle irons, weighing about 4 cwt. per yard.

The passenger trains consist of a 4-wheeled engine, and of a carriage with an upper story, capable of accommodating 80 persons. This carriage is pushed up by the engine, instead of being drawn, as on other railways, and in descending the mountain the engine is in front, so as to sustain the carriage, which, however, could descend entirely by itself, and is entirely under control of powerful brakes.

The speed on this line is certainly not great, occupying about 1¼ hours from the lake to reach the summit, a distance of about 5,500 metres (rather under 3½ English miles). The engine is of 120-horse power, and the steam is produced in a tubular boiler, which is vertical when on the steep gradient. The weight of the engine is 10 tons. A toothed wheel is fixed on the driving angles, and makes 1 revolution to 3 of the steam engine. This wheel works into the rack, which is placed in the centre of the line, and it is in this manner that adherence is obtained for overcoming the gradient. The engine is prevented from running off the rail by strong angle-irons, which are fixed to the under part, so as to prop it on each side of the rack. In descending, a powerful new brake is used.

The carriages are composed of 2 stories with 9 seats each, and are capable of accommodating 45 persons on the lower story, and 36 on the upper.

The cost of the line, including 3 engines and 3 carriages, was 350,000 thalers (£56,000).

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On the Great Sun-spot of 1843.—One of the largest and most remarkable spots ever seen on the sun's disc appeared in June, 1843, and continued visible to the naked eye for 7 or 8 days. The diameter of this spot was, according to Schwabe, 74,000 miles; so that its area was many times greater than that of the earth's surface. Now, it has been observed during a number of sun-spot cycles that the larger spots are generally found at or near the epoch of the greatest numbers. The year 1843 was, however, a *minimum* epoch of the 11-year cycle. It would seem, therefore, that the formation of this extraordinary spot was an anomaly, and that its origin ought not to be looked for in the *general cause* of the spots of Schwabe's cycle. As having a possible bearing on the question under consideration, let us refer to a phenomenon observed at the same moment, on the 1st September, 1859, by Mr. Carrington, at Redhill, and Mr. Hodgson, at Highgate. "Mr. Carrington had directed his telescope to the sun, and was engaged in observing his spots, when suddenly 2 intensely luminous bodies burst into view on its surface. They moved side by side through a space of about 35,000 miles, first increasing in brightness, then fading away. In 5 min. they had vanished. . . . It is a remarkable circumstance that the observations at Kew show that on the very day, and at the very hour and minute of this unexpected and curious phenomenon, a moderate but marked magnetic disturbance took place, and a storm, or great disturbance of the magnetic element, occurred 4 hours after midnight, extending to the southern hemisphere." The opinion has been expressed by more than one astronomer that this phenomenon was produced by the fall of meteoric matter upon the sun's surface. Now the fact may be worthy of note that the comet of 1843, which had the least perihelion distance of any on record, actually grazed the solar atmosphere about 3 months before the appearance of the great sun-spot of the same year. The comet's last distance from the sun was about 65,000 miles. Had it approached but little nearer, the resistance of the atmosphere would probably have brought its entire mass to the solar surface. Even at its actual distance it must have produced considerable atmospheric disturbance. But the recent discovery that a number of comets are associated with meteoric matter, travelling in nearly the same orbits, suggests the inquiry whether an enormous meteorite following in the comet's train and having a somewhat less perihelion distance, may not have been precipitated upon the sun, thus producing the great disturbance observed so shortly after the comet's perihelion passage.

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The Conservators of the Thames have framed a new set of by-laws for the better navigation of the river, and especially with a view to the prevention of collisions, for which they intend to obtain an order in council.

# ON THE DURABILITY OF CAST AND WROUGHT IRON FOR ENGINEERING STRUCTURES.*

By G. J. CROSBIE DAWSON, ESQ., C. E.

From "The Artizan."

It is rather remarkable, I always think, that our early engineers rarely used iron in any of their structures, and it is only within the last few years that the valuable properties of the metal seemed to have been universally acknowledged by the whole profession as applicable to almost every kind of engineering work. There is no other substance of greater use to man, being so well adapted to form such a variety of things, tools of almost every description, machines of all kinds, steam engines, etc., and there is no other metal more abundant throughout the world than iron; it is found in almost every inorganic body, and where iron ore is found in plenty there generally are seams of coal adjacent. Iron has been used from the very earliest times, we read of it in the 4th chap. of Genesis, and 22d verse. We know that iron was exported from this country before the Roman invasion, and the ancient Britons must have understood how to work the metal for forming their scythes, hooks, spear-heads, and implements of warfare. Undoubtedly we owe our great wealth and prosperity as a nation, to our endless supply of iron and coal. It is less than 100 years ago, however, that iron was first used in engineering structures. The very first iron bridge constructed in this country, was, I believe, the bridge at Coal Brook Dale over the Severn, built 92 years ago, consisting of semi-circular cast iron arched ribs, and the bridge over the River Wear at Sunderland, built in 1790, of cast iron, would probably be the second.

Telford constructed many iron bridges, the first of which was that at Buildwas in Shropshire, across the Severn, in 1796, built of arched ribs of cast iron. His suspension bridge across the Menai Straits was commenced in 1825. Rennie's Southwark Bridge over the Thames was commenced in 1815. It was at the time, and even still is, I believe, the largest cast iron span, that of the centre arch being 240 ft. It was not until about the year 1832, that the first attempts were made to substitute wrought for cast iron, by riveting rolled plates together and forming girders by means of riveting horizontal to vertical plates with angle iron. (Though wrought iron plates had been used in the manufacture of steam-engine boilers, and ships, many years previously; the first iron boat having been constructed in 1822, at the Horseley Iron Co.'s works at Tipton.) But girders so made were used only in the construction of floors or as deck beams in ships, until about 10 years later, when Sir William Fairbairn patented several improvements and designed the tubular girder. The first tube of Robert Stephenson's great bridge, the Britannia, over the Menai Straits, was commenced in 1847, and the bridge was completed in 1850. The Conway Bridge was built about the same time, and since then, owing to the great success of these works and the numerous experiments that have been made with iron, and the improvements that have taken place in its manufacture, wrought iron has been most extensively used for every kind of engineering work, but more particularly for bridges. On our old railways, how few iron bridges there are, and on our new railways how few stone, brick, or timber bridges, but almost all iron. Our architects are now also using iron to a very great extent in their buildings. In the Northwestern Hotel, just completed at Lime-street station, Liverpool, Mr. Waterhouse has used wrought iron girders for all the floors, passages, galleries, staircases, etc., and cast-iron columns. Our fine old ships also, three-decker men-of-war, "the good wooden walls of old England" are now fast becoming a thing of the past, and are being replaced by a magnificent fleet of iron armor-plated vessels, and all these transformations have taken place within the last few years. A bridge, pier, breakwater, lighthouse, etc., built of iron would be, as we all know, about half the cost of the same built of stone; but we know that the stone will stand for centuries if properly constructed, and with good foundations, whereas we do not feel quite so sure about the iron, as to its durability, not

* A paper read before the Civil and Mechanical Engineering Society.

having had the experience of it. Although experiments of all kinds have been made by some of our most eminent engineers, to ascertain the specific gravity, tenacity, crushing force, and the breaking weights and deflections, etc., of different kinds of iron, various shaped girders, etc., yet no really definite conclusion as to the exact durability of iron in engineering structures, can be arrived at, though we can conjecture with tolerable certainty. Iron in its three different states or forms, viz., wrought iron, steel, and cast iron, though considerably lighter than most other metals, as copper, brass, lead, etc., is by far the most tenacious of all them. An iron wire $\frac{1}{3}\frac{1}{2}$th of an in. in diameter will bear a weight of 60 lbs.

| | | |
|---|---|---|
| The tenacity of | steel in lbs. per sq. in. is..... | 120,000 |
| " " | wrought iron " " ..... | 70,000 |
| " " | cast-iron " " ..... | 19,000 |

But the time not permitting, and the subject of this paper being the durability of wrought and cast iron, I must exclude steel, though I believe the time is not far distant when it will be extensively used in engineering constructions. Some hundreds of miles of rails on the London and North Western Railway, have during the past year or two been relaid with steel rails. Mr. Kirkaldy has for some years been making a series of experiments on the resistance of plates of steel to crushing force, and Mr. George Berkley, in a paper read before the Institution of Civil Engineers, about this time last year, drew attention to the experiments which had lately been tried with steel, more especially Bessemer steel, which experiments he considered justified the adoption of the following conclusions :—

1. "That Bessemer steel would bear before rupture a minimum tensile strain of 33 tons per sq. in. of section, and stretch about 1 in. in 12 in. of its length.

2. "That the same material would bear, either in tension or in compression, a minimum stress of 17 tons before the extensions or reductions of length per unit of strain became irregular or excessive as compared with those which had preceded them; in other words, before the yielding point of the material was reached.

3. "That this material would probably contain about 45 per cent. of carbon, chemically combined with the iron; and,

4. "That this description of steel, if properly made and annealed, was as uniform in quality as wrought iron, and therefore might be employed (precautions being taken to test its quality as a substitute for wrought iron), while allowing an increase of strain of 50 per cent. to be imposed upon it."

Of the innumerable ores and the various formations in which iron is found, and of the preparation and smelting of the ores, etc., I will not now speak, but will at once proceed to the question as to the durability of iron, and the effects that the atmosphere, moisture, smoke, sea-water, changes of temperature, etc., have upon it. There is not the slightest doubt that iron absorbs to a certain extent the oxygen or the carbonic acid in the atmosphere, and gradually corrodes, and more so when subjected to changes of atmosphere, or exposed to the action of water, and especially sea-water. Other metals, such as copper or lead, when soldered or placed in contact with iron, act chemically upon it, and the iron more quickly softens and corrodes. For instance, the iron railings round the parks and squares, and round the areas of houses, etc., invariably begin to corrode at the bottom, where they are bedded into the stone with lead. I was noticing the railings round Leicester Square the other day; the iron at the bottom is, in many cases, entirely worn away or eaten to the thickness of a thin wire. Then again, the cast-iron plates which were affixed, according to Sir Humphrey Davy's proposition, to the bottom of ships to protect the copper sheathing, very rapidly became softened, and the ordinary copper sheathing fastened to ships by means of iron rails invariably begins to corrode, as do also the nails, at the places of contact by galvanic action. Sea-water has the effect both of softening iron and oxidizing it, but the rate of oxidation is slow. Mr. Mallett states, after making several experiments, that "cast iron freely exposed to the weather at Dublin, and to all its atmospheric precipitations, was corroded nearly as fast as if in clear sea-water, when the specimens in both cases were wholly unprotected." Doubtless, if the iron is always entirely under water, oxidation goes on more slowly than when the metal is exposed alternately to air and water. However, as I before observed, the rate of oxidation is slow. The cast-iron piles that the late Sir William Cubitt cased the entrance basin of the

Lowestoft harbor with in 1832, are now almost as perfect as when driven. The cast-iron piles for Herne Bay pier were driven in 1838 by Telford, and those for Southend pier in 1844, and are still in a most perfect state, as also Rennie's dock gates at Sheerness. The cast-iron piles in Margate jetty, erected in 1853, the wharf wall at Victoria Docks, the piers of Chelsea Suspension Bridge, of Charing Cross Railway Bridge, and of Lambeth Bridge, etc., show little or no signs of corroding. The latter, however, are in fresh water. Sea-water itself frequently provides an excellent protection against oxidation to the iron in the shape of mollusks, which little shell fish completely cover and incrustate the metal, and when this incrustation has been removed, the iron has been found to be smooth and quite free from any deterioration by the action of the sea-water. The *softening* of cast iron, Mr. E. B. Webb tells us, in a pamphlet on "Iron Breakwaters," is a process not clearly understood. He says, "cast iron will soften in cylinders and pipes used in mines, as well as in piles standing in sea-water; after softening under sea-water it will at times become hard again on exposure to the air." Cast iron *has* been taken up after immersion in sea-water, utterly decomposed, owing most probably to the iron having been cast of the softest metal, there being such great variety in the quality of cast iron. Great care should therefore be taken in selecting a quality of iron suitable for the work in which it is to be used, as the power of the various classes of cast iron to resist the action of sea-water, will vary according to quality. The necessity of substituting iron for wood or stone, in piers, lighthouses, breakwaters, etc., is due to the perishable nature of the former and the costliness of the latter. Mr. Webb in his pamphlet says: "It appears that the action of the sea-water is powerful in the greatest degree, when the iron is composed of large crystals, and especially when there is irregularity in the crystallization. It may be said that the softer the iron the greater is the liability to decomposition. Between the limits of extreme softness and decay on the one hand, and extreme hardness and durability, with brittleness, on the other, we have to make the selection. It has been stated that chilled cast iron corrodes faster than green sand castings, that all castings intended for use in sea-water should be cooled in the sand to insure uniformity in the crystals, and that Welsh iron is the best."

I will now turn to that portion of my subject which I think will be of most interest, viz., the application of cast and wrought iron to bridge construction. Wrought iron, as I before stated, was not, until about 30 years ago, employed in bridge construction, though cast iron has been made use of for nearly 100 years. Now, however, cast iron is not employed as much as formerly, for although cast iron has greater power to resist crushing strains, and is therefore preferable for columns, supports, and struts, etc., the crushing force of cast iron in lbs. yer sq. in. being about 92,000, and that of wrought iron about 38,000, yet for girders for bridge construction, the same amount of dependence cannot be placed in it as in wrought iron.

Mr. Rennie, some years ago, made a series of experiments on the effect of the changes of ordinary temperature on cast iron, particularly on the cast-iron arches of Southwark Bridge, which is the largest cast-iron span, I believe, that there is, and he found that the rise in each arch, the span being 240 ft., and the versed sine 23 ft. 1 in., is about $\frac{1}{40}$ of an in. for each deg. of Fahrenheit, making $1\frac{3}{4}$ in. for a difference of 50 deg. The arches have no alternative but to rise or fall, being bedded against the abutments. Cast-iron arches are of course on the same principle as stone or brick arches, and derive their strength and stability by transferring the effect of the loads placed upon them to the abutments. Cast iron is chiefly now, however, used in bridge construction in the form of horizontal girders, and especially on railways, where we are frequently pinched for headway, as the depth of the structure is merely that which is required for the flanges of the girders.

40 ft. is generally considered the maximum span for cast-iron girders, but the practice on the London and North Western Railway latterly has been, never to employ cast iron for spans over 25 ft. It is certainly not so safe as wrought iron, and the same degree of dependence cannot be placed in it. When testing the girders at the foundry, it is impossible to tell whether an extra ton of strain to the amount applied, would not have broken

them. Then we can never be quite sure of perfect castings, of perfect uniformity in the flanges, of the absence of air bubbles, etc. Then, again, in 9 cases out of 10, girders are cast on their sides at the foundry, in order to save time and trouble, and the consequence is that one edge of the flange, as also one side of the web, consists of the scum of the iron; and another great objection to this mode of casting is the difficulty of preventing lateral twists in the girder. By having the girder cast upright, standing on its bottom, all this is avoided; the spurious part of the iron will be in the top flange, where it is of not much consequence, and the girder is more likely to be perfectly straight. In my opinion engineers should always have a special clause inserted in their specifications, insisting on the girders being cast upright. The cheapness of cast iron is in its favor, being about half the cost of wrought, but the cost of wrought iron *now*, is even less than I have known cast iron to be, the prices fluctuate so very much. On the widening of the Trent Valley Railway, on which I am the resident engineer, the price of wrought-iron girders, including riveting, testing, painting, and fixing complete, is only £13 10s., whereas in 1861, the price for the cast-iron girders, on the Edge Hill and Garston Branch Railway was £13 10s. Since I have been an assistant engineer on the London and North Western Railway, during the last 10 years, the prices of iron work have varied from £22 to £13 10s. per ton, for wrought-iron girders complete in every way, for bridges of ordinary spans, and from £13 to £7 per ton, for cast-iron girders complete in every way, the lower prices being those of the present time. In practice, however, the difference in cost between wrought and cast iron is not after all so great, as owing to the thick flanges of cast-iron girders, the weight of them is nearly double that of wrought-iron girders of the same size. It is found that wrought iron corrodes rather faster than cast iron. Mr. Mallett gives the relative oxidation in moist air as follows :—

| | |
|---|---|
| Cast iron | .42 |
| Wrought iron | .54 |
| Steel | .56 |

He also states that the depth of corrosion of plates of Low Moor iron, as deduced from his experiments, would be in one century:

| | |
|---|---|
| In clear sea-water | .215 of an inch. |
| In foul sea-water | .404 " |
| In clear fresh-water | .035 " |

Mr. Baker, the engineer-in-chief of the London and North Western Railway, and Mr. Ramsbottom, the mechanical engineer, together with Mr. Lee, lately inspected and thoroughly examined the Britannia and Conway tubes, both externally and internally, and found the former bridge in excellent preservation, having been recently painted, but portions of the under side of the cellular top of the Conway tube, which had not been painted for four years, and which caught the smoke of the engine chimneys, showed very slight signs of corrosion. They had some of the "scale" removed from the plates, and Dr. Percy analyzed it and found it to contain about 41 per cent. of metallic iron. The accompanying table shows the details of analysis :

SCALE FROM THE CONWAY TUBE.

First analysis of Dr. Percy from the two following samples, which were rubbed and scraped from one and the same area of the same plate:

No. 1.

From that rubbed off an area of plate 2'.4"×1'.9".

| | Grains. |
|---|---|
| Total weight | 2,810.7 |
| Containing | 1,229.9 of iron |

or 43.65 per cent of metallic iron.

No. 2.

From that scraped off an area of plate 2'. 4"×1'.9".

| | Grains. |
|---|---|
| Total weight | 1,316.3 |
| Containing | 532.8 of iron |

or 40.48 per cent of metallic iron.

| Detail of Composition. | Per cent. of total of the above quantity. |
|---|---|
| Peroxide of iron | 58.43 |
| Protoxide of iron | 3 34 |
| Metallic iron | 0.15 |
| Protoxide of lead | 2 29 |
| Copper | traces. |
| Sand (chiefly silica) | 10.90 |
| Carbonaceous matter (soot) | 4.97 |
| Water | 15.23 |
| Sulphuric acid | 3 30 |
| | 98.61 |
| Peroxide of iron | 54 90 |
| Protoxide of iron | 2.64 |
| Metallic iron | traces. |
| Protoxide of lead | 1.11 |
| Copper | traces. |
| Sand (chiefly silica) | 14 95 |
| Carbonaceous matter (soot) | 5.70 |
| Water | 15.65 |
| Sulphuric acid | 4.14 |
| | 99.09 |

Second analysis by Dr. Percy, from the two following samples, which were rubbed and scraped from one and the same area of the same plate:

No. 1.

From that "rubbed" off an area of plate 3′ 0″ × 1′.9″.

| | Grains. |
|---|---|
| Total weight | 4.614. |
| Containing | 1,912.1 of iron |
| or 41.44 per cent. of metallic iron. | |

No. 2.

From that "scraped" off an area of plate 3′.0″×1′.9″

| | Grains. |
|---|---|
| Total weight | 5,703 3 |
| Containing | 2,255.7 of iron |
| or 39 55 per cent. of metallic iron. | |

The plates from which the rust was taken are ⅓ in. thick, and Mr. Baker says, that assuming the whole of this percentage did belong to the original iron plates, it would lead to the conclusion that under a continuation of similar circumstances, a period of time amounting to upwards of 1,200 years would be required for the entire corrosion of the plate. Messrs. Baker and Ramsbottom recommend that the painting of the tubes from time to time be continued whenever the paint shows the least symptoms of decay, and that the paint selected for this purpose should be of a first rate quality, and analyzed before being used, to see that it does not contain any matter injurious to the iron, and with such precautions they cannot give any practical limit to the endurance of these magnificent structures. These bridges have been built about 20 years. The sensibility to changes of temperature of the tubes of the Britannia Bridge, owing to their large surface, is very remarkable. The tubes become curved towards the point from which the sun shines, so much so, that between sunrise and sunset the centre is lifted fully an inch, as well as drawn sideways throughout an equal space. The total length of the Britannia tubular bridge is 1,513 ft., and an increase of temperature of 26 deg. Fahrenheit only causes an increase of length of 3¼ in.

Professor F. Grace Calvert, at a recent meeting of the Manchester Literary and Philosophical Society, read a most interesting paper on the oxidation of iron. He gave the results of a series of experiments he had made, at the instigation of Sir Charles Fox, to prove whether the oxidation of iron is due to the direct action of the oxygen of the atmosphere, or to the decomposition of its aqueous vapor, or whether the very small quantity of carbonic acid which it contains determines or intensifies the oxidation of metallic iron? The conclusions he arrived at are that "pure and dry oxygen does not determine the oxidation of iron, that moist oxygen has only feeble action; dry or moist pure carbonic acid has no action, but that moist oxygen containing traces of carbonic acid acts most rapidly on iron, giving rise to protoxide of iron, then to carbonate of the same oxide, and last to a mixture of saline oxide and hydrate of the sesquioxide of iron. These facts tend to show that carbonic acid is the agent which determines the oxidation of iron, and justifies the assumption that it is the presence of carbonic acid in the atmosphere, and not its oxygen or its aqueous vapor, which determined the oxidation of iron in common air. Although this statement may be objected to at first sight, on the ground of the small amount of carbonic acid gas existing in the atmosphere, still we must bear in mind that a piece of iron when exposed to atmospheric influences comes in contact with large quantities of carbonic acid during twenty-four hours." Professor Calvert ends his paper by stating as a fact "that carbonic acid promotes oxidation," and that "caustic alkalies prevent the oxidation of iron." He also states "that the carbonates and bicarbonates of the alkalies possess the same property as their hydrates," and "that if an iron blade is half immersed in a solution of the above mentioned carbonates, they exert such a preservative influence on that portion of the bar which is exposed to an atmosphere of common air (oxygen and carbonic acid), that it does not oxidize even after a period of two years. Similar results were obtained with sea-water to which had been added carbonates of potash and soda."

Mr. Baker usually has all wrought iron work immersed in boiling linseed oil before leaving the manufactory, and afterwards painted with four or five coats of best oil paint, in order to protect the iron from rust. In most of his specifications he has a special clause to this effect. There is not the slightest doubt but that, if the above was always done, it would effectually keep the iron from corroding for many years, and after a lapse of time, when signs of oxidation began to appear, if the iron was again carefully cleaned

and repainted, corrosion would be entirely prevented. But very often the above precautions are not taken and the iron does not get thoroughly painted, and frequently there is rust on the iron before receiving the first coat of paint. A resident engineer cannot be too careful in seeing to these matters. There are numerous anti-oxidation paints, one of the best of which, I believe, to be Hubbuck's patent white zinc paint, as "by virtue of a semi-galvanic action on iron, it enters the pores and forms an amalgam of the two metals, which protects the iron from decay or incrustation." The old Hungerford Suspension Bridge was in 1853 painted with the above, and it effectually preserved the iron from corrosion for 10 years, up to the time of its being pulled down for the new Charing Cross Railway Bridge. Another very good paint, from all accounts, is a silicated paint, supplied by "the Native Silicate Paint Company," as it causes the "substance of the paint to petrify" round the metal, and so preserve it, and it is said not to peel off. Small box girders, or tubular girders with cellular tops are objectionable on account of the large extent of surface exposed to corrosion, and of the difficulty there is in painting the inside; but by stopping up the ends of the cells so as to exclude the changes of atmosphere and moisture, the work of corrosion may be greatly diminished. One quarter of an inch, Mr. Stoney says, "may be assumed to be the minimum thickness that experience sanctions for the plating of permanent structures. A thinner plate than this may with care last for years, but few engineers would wish to risk the stability of any important structure on the chance of such frequent attention to prevent corrosion as so great a degree of tenuity would require."

The most important question of all, however, with respect to the durability of wrought-iron girders for bridges, etc., is, the amount of power of resistance that iron has to withstand repeated strains. It is of even more consequence than corrosion, and until lately has not been considered at all.

Sir William Fairbairn has recently been giving his attention to the subject, and making experiments to ascertain to "what extent vibratory action, accompanied by alternate severe strains, affects the cohesive force of bodies. It is immaterial whether the body be crystalline, homogeneous, or elongated into fibre, such as cast or wrought iron; the question to be solved is, how long will a body of this description sustain a series of strains produced by impact (or the repeated application of a given force) before it breaks? In the case of bridges and girders, this is a subject on which no reliable information has yet been given which may be considered as a safe measure of strength for the guidance of the engineer or architect." Sir William goes on to say, "of the resisting powers of material under the severe treatment of a continuous change of strain, such as that which the axles of carriages and locomotive engines undergo when rolling over iron jointed rails and rough roads, we are very imperfectly informed. Few facts are known, and very few experiments have been made bearing directly on the solution of this question. It has been assumed, probably not without reason, that wrought iron of the best and toughest quality assumes a crystalline structure when subjected to long and continuous vibration, that its cohesive powers are much deteriorated, and it becomes brittle, and liable to break with a force considerably less than that to which it had been previously subjected. This is not improbable, but we are apparently yet ignorant of the causes of this change; and the precise conditions under which it occurs." The breaking weight of wrought iron varies, as we all know, from about 20 to 24 tons per square arch of section, and the Board of Trade requirement in a wrought-iron bridge is that "the greatest load which can be brought upon it, added to the weight of the superstructure, should not produce a greater strain on any part of the material than 5 tons per sq. in."

It is usual in specifications to state the particular description of iron to be used, and the amount of strain per sq. in. it is required to sustain without having its elasticity injured, and also the amount before fracture, and it is also usual for the engineer to have samples of the plates tested. Mr. Baker and Mr. Stevenson generally now have specimens forwarded to Mr. Kirkaldy for testing and experimenting upon. When examining wrought-iron girders at the works, I generally carry a stamp with my name on with me, and mark a plate with it, or a T or L iron, which I have cut out and tested, in order

to ascertain if the same quality of iron has been used for the girders as was previously tested and approved of for the work. A soft, tough iron, if broken gradually, gives long silky fibres of leaden-gray hue, which twist together and cohere before breaking. A medium even grain with fibres denotes good iron. Badly refined iron gives a short blackish fibre on fracture. A very fine grain denotes hard steely iron, likely to be cold, short, and hard. Coarse grain, with bright crystallized fracture or discolored spots, denotes cold short, brittle iron, which works easily when heated and welds well. Cracks on the edge of a bar are indications of hot short iron. Good iron is readily heated, is soft under the hammer, and throws out few sparks.

Sir William Fairbairn considering the Board of Trade requirement of 5 tons per sq. in. not sufficiently definite to secure in all cases the best form of construction, and that the margin for errors of design and other practical defects being hardly sufficient, had a girder made purposely for experimenting upon of 20 ft. span, and of the following dimensions:--

Top plate 4 in. × ½ in.
2 angle irons 2" × 2" × $\frac{5}{16}$".
Bottom plate 4 in. × ½ in.
2 angle irons 2" × 2" × $\frac{3}{16}$".
Web plate ½" thick.

Depth of girder 16 in., weight of it 7 cwt. 3 qrs., and breaking weight 12 tons.

Sir William Fairbairn, in order to arrive at correct results, and to imitate as nearly as possible the strain to which bridges are subjected by the passage of heavy railway trains, invented an apparatus specially adapted for that purpose, and designed to lower the load quickly upon the beam in the first instance, and subsequently to produce a considerable amount of vibration,

From the experiments made it was ascertained "that wrought-iron girders of ordinary construction are not safe when submitted to violent disturbances with a load equivalent to ⅓ the weight that would break them. They, however, exhibit wonderful tenacity when subjected to the same treatment with ¼ the load; and assuming that an iron girder bridge will bear with this load 12,000,000 changes without injury, it is clear that it would require 328 years, at the rate of 100 changes per day before its security was affected. It would, however, be dangerous to risk a load of ⅓ the breaking weight upon bridges of this description, as according to the last experiments, the beam broke with 313,000 changes; or a period of 8 years, at the same rate as before, would be sufficient to break it. It is more than probable that the beam might have been injured by the previous 3,000,000 changes to which it had been subjected; and assuming this to be true, it would then follow that the beam was progressing to destruction, and must of necessity at some time, however remote, have terminated in fracture."

The following tables show the summary of results obtained by Sir William Fairbairn's experiments:

FIRST SERIES OF EXPERIMENTS.

*Beam 20 ft. between the supports. Breaking weight 12 tons.*

| No. of experiment. | Date. | Weight laid on middle of beam in tons. | Number of changes of load. | Strain per square inch on bottom flange. | Strain per square inch on top flange. | Deflection in inches. | Remarks. |
|---|---|---|---|---|---|---|---|
| 1 | From March 21 to May 14, 1860. | 2.96 | 596,790 | 4.62 | 2.58 | .17 | |
| 2 | From May 14 to June 26, 1860. | 3.50 | 403,210 | 5.46 | 3.05 | .23 | |
| 3 | From July 25 to July 28, 1860. | 4.68 | 5,175 | 7.31 | 4.08 | .35 | Broke by tension at a short distance from the centre of the beam. |

The number of 1,005,175 changes was attained before fracture, with varying strains upon the bottom flange of 4.62 tons, 5.46 tons, and 7.31 tons per sq. in.

SECOND SERIES OF EXPERIMENTS.

*Beam 20 ft. between the supports. Breaking weight 12 tons.*

| No. of experiment. | Date. | Weight laid on middle of beam in tons. | Number of changes of load. | Strain per square inch on bottom flange. | Strain per square inch on top flange. | Deflection in inches. | Remarks. |
|---|---|---|---|---|---|---|---|
| 4 | August 9, 1860.. | 4.68 | 158 | 7.31 | 4.08 | — | The apparatus was accidentally set in motion. |
| 5 | August 11 and 12. | 3.58 | 25,742 | 5.59 | 3.12 | .22 | |
| 6 | From Aug. 13, 1860, to Oct. 16, 1861..... | 2.96 | 3,124,100 | 4.62 | 2.58 | .18 | |
| 7 | From Oct. 18, 1861, to Jan. 9, 1862..... | 4.00 | 313,000 | 6.25 | 3.48 | .20 | Broke by tension as before, close to the plate riveted over the previous fracture. |

Here the number of 3,463,000 changes was attained when fracture ensued.

From these tables it is evident that wrought-iron girders, when loaded to the extent of a tensile strain of 7 tons per sq. in., are not safe, if that strain is subjected to alternate changes of taking off the load and laying it on again, provided a certain amount of vibration is produced by that process; and what is important to notice is, that from 300,000 to 400,000 changes of this description are sufficient to insure fracture.

It must, however, be borne in mind that the beam from which these conclusions are derived had sustained upwards of 3,000,000 changes, with nearly 5 tons tensile strain on the sq. in., and it must be admitted from the experiments thus recorded that 5 tons per sq. in. of tensile strain on the bottom of girders, as fixed by the Board of Trade, appears to be an ample standard of strength.

Mr. Baker specified that the iron-work of the bridge over the river Mersey at Runcorn, which is one of the largest and finest of the bridges in this country, "should be of such quality as shall bear a strain of at least 14 tons per sq. in. of sectional area, without having its elasticity injured, and under this strain the extension of a bar 12 ft. long by 10″ by 1″ shall not exceed $\frac{1}{8}$ of an in., and fracture shall not take place under any strain less than 22 tons per sq. in. of section."

Mr. George Berkley, in a paper read before the Institution of Civil Engineers, this time last year, stated "that the strength of wrought iron varied with the quantities of work involved in the production of the form of the material tested. This was proved by the fact, that a bar of iron 1 in. sq., which would break with a strain of 26 tons, would, if drawn down to the form of wire $\frac{1}{32}$ of an in. in diameter, bear a strain of 40 tons per sq. in. The strength to be relied on in practice would probably be best represented by the minimum strain that 1 sq. in. would bear without rupture, and by the amount of stretch which would take place in a given length before it broke."

Simplicity of construction is the great point to be aimed at in designing wrought-iron girders. All plates and parts of girders should be of the same pattern, easily put together, and accessible for preservation or repair. All rivet-holes should be drilled, as punching the plates undoubtedly weakens them, by straining the fibres of the metal; and all the ends and edges of plates and the butt joints of angle irons should be planed.

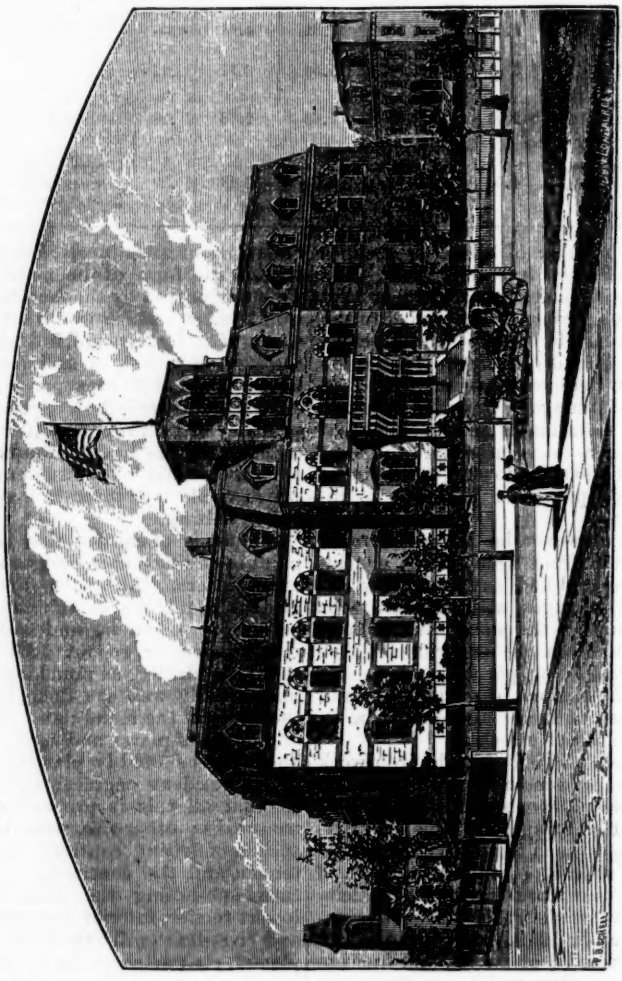
The resident engineer should himself see that all this is properly done at the ironworks; otherwise, with the present system of letting contracts to the lowest tender, and the contractor again in his turn sub-letting the iron-work to the lowest tender, inferior iron will be used, and rivet-holes will be punched, plates not planed, etc.; in short, bad work executed in every way, in order to make it pay.

So the resident engineer cannot be too careful in thoroughly looking after these matters, remembering the enormous responsibility on his shoulders, where the lives of the public are at stake.

## STEVENS INSTITUTE OF TECHNOLOGY, HOBOKEN, N. J.

We have the pleasure of giving below an engraving of the Stevens Institute of Technology, at Hoboken, N. J.

As the only special school of Mechanical Engineering in America, the institution excites unusual interest in our readers, and we intend, in a later issue, to describe fully this fine school, its workshops, laboratories, and apparatus, and the proposed course of instruction.



We can here only state that the school approaches somewhat in its character the technical schools of Germany, the aim of its founder and its managers being to combine, as far as it may be done in the schools, the practical with the theoretical, the experimental with the rational. It is with this object in view, that high scientific instruction is intended to be offered to the student, while at the same time

actual manipulation of tools and apparatus will be taught in the workrooms and in the chemical and physical laboratories, and a familiarity with science and its relations to the arts will be thus communicated, that can in no other way be attained.

We trust that it will not be many years before the graduates of such schools shall destroy the force of the statement now so often heard, that our scientific men very generally know nothing of every-day work, and our practical men too often exhibit a shameful ignorance of the scientific principles involved in their own work. He who most successfully combines theory and practice, as those words are usually but unfortunately used, is the successful engineer of the future.

## IRON AND STEEL NOTES.

NOTWITHSTANDING the continual development of the iron trade in the United States—one of our best customers—there does not seem to be the slightest probability of our business transactions with America being affected. The demand is greater than ever; and as long as the American ironmaster requires $75 per ton for bar iron to make it worth his while to manufacture, we shall be sure of a market there. In 1870 we sent to the United States 45 per cent. of all the bar iron consumed. And as to the old gossip about the Americans importing our iron and steel for the purpose of making up into tools and machinery, and sending them to our markets in successful competition with our own manufacturers, we do not believe a word about it. Where such has been done it has been in a market where our cheapest, and of course our commonest articles have been sent, and as the American tool is generally a good one, it has been preferred to ours. If our merchants would send abroad our very best made goods, and be satisfied with a moderate commission, a different result would be apparent. As it is, they cannot compete with us in price, neither can they in quality. Therefore our ironmasters and manufacturers have no reason to be afraid of American competition. Another of our great customers, the Russian Empire, continues still to buy largely in our markets, and seems likely to make increasing demands upon us. Iron manufacture there does not seem to thrive. In Germany, just before the war broke out, a very large trade was being done in both coal and iron. It is said that the production of coal in Germany for 1860 amounted to 12,347,828 tons, of 2,000 lbs., and in 1869 to 26,774,368 tons; an increase in that time of over 14,000,000 tons, or equal to 117 per cent. This favorable result is still further enhanced to the trade by the advance in prices. Thus the money value in 1860 was 23,379,199 thalers, and in 1869, 51,928,403 thalers, giving an increase of 25,549,204 thalers, being equivalent to 97 per cent.; of this amount Prussia produces 88¼ per cent.; Saxony, 9½ per cent.; Bavaria, 1½ per cent.; and the remaining States ¼ per cent. The exports of German coal in 1869 amounted to 4,000,000 tons, of which France took 1,700,000 tons, the Netherlands, 1,300,000 tons; and the imports were 1,800,000, making the home consumption 25,000,000 tons. These figures show the steady growth of this industry, and also that of iron, which is the most closely allied to the coal trade. The consumption of coal in Germany has risen 9½ per cent. per head of the population since 1860, while the population itself has only increased in the same time about 14½ per cent. The product for 1870 will fall off considerably from the war in France, which checked industry, depriving the collieries and ironworks of hands, and will have a somewhat similar effect upon 1871, the first half of which has been almost lost. The prices of pig iron per ton in Germany to-day are:—Foundry No. 1, 28 to 40 thalers; No. 2, 36 to 37 thalers; Gray Forge, 32½ to 33 thalers; White and Mottled, 32 to 32½ thalers. Manufactured iron is quoted high, bar being 72 to 76 thalers per ton. The high price of coal has equalized the losses on production, and collieries have generally paid 10-20 thalers per cent. for it upon their capital. One of the effects of the cession of French territory to Germany is noteworthy as including in the portion ceded 25 iron furnaces, with a production of 204,579 tons a year, and collieries with a yearly product of 506,640 tons. Thus there is not much to fear in the shape of German rivalry. They have got to put their house in order before they can begin the race with us. As for unhappy France, it is impossible to say what she is likely to do. It is said that the Government contemplates levying heavy import duties upon all raw materials, this will be sure to provoke bad feeling with the manufacturers of that country. Little Belgium is busy doing her best, but her largest production is so small as not to affect our market. Therefore from none of these quarters are we likely to be hindered in our trade, and both iron-master and iron-worker may look forward with confidence to the future. The reports which we have received from the various iron-making districts are still of an encouraging character; and the markets of Glasgow, Middlesbro', Wolverhampton, and Birmingham, as well as those of South Wales, are firm as to prices, and full of lively anticipation for the future.—*Iron Trade Circular.*

IRON AT LOW TEMPERATURES.—At a recent meeting of the Philosophical Society of Manchester, several communications were submitted, dealing with the influence of low temperature in producing brittleness in iron and steel. Mr. Wm. Brockbank contributed a paper on this subject. The author stated that he had instituted a series of experiments for the purpose of ascertaining the effects of cold upon the strength of iron. He found that by using a mixture of metals consisting of Cleator hematite, Pontypool cold blast, Blaenavon cold blast, and Glengarnock hot blast, with some good scrap iron, a considerable decrease of strength in the bars was perceptible as the temperature decreased. The experience of several ironfounders as follows, was also adduced in confirmation of the results above named:—(1) Pig iron breaks most easily in frosty weather, and castings are also more liable to fracture at low temperatures. (2) Special care has to be exercised in rolling mills during frosty weather, to pre-

vent the breakage of rolls. (3) The cast iron wheels of the chaldron wagons, used on the Stockton and Darlington Railway, are found to fracture very frequently in frosty weather. From the evidence collected, the author concludes that the strength of cast iron is very materially lessened by severe cold. In his experiments with wrought iron, the author found the same general principal applicable. Mr. Bouch had demonstrated that a bar of round iron, 1¼ in. in diameter, was far more brittle at a temperature of 26 deg., than it was at the ordinary temperature of the workshop. Mr. Peel, of Manchester, obtained corroborative results from tests applied to boiler plates. Railway bars had also been tested by the author at the Darlington Iron Works. It was found that rails of high quality failed to pass the requisite test in frosty weather, whereas, at ordinary temperatures, a failure with this class of rail was a very rare occurrence. The author, therefore, maintained that bar iron, boiler plate, wire billets, and r ils are most materially weakened by the action of intense cold, losing their toughness, becoming quite brittle under sudden impact, and having their structures changed from fibrous to crystalline.

At the same meeting, Sir W. Fairbairn, F. R. S., communicated the results of his experiments upon the subject alluded to by Mr. Brockbank. He had found that the resistance to a tensile strain is as great at the temperature of zero, as it is at 60 deg. and upwards, until it attains a scarcely visible red heat. The mean breaking weight in tons, per sq. in., was (in his experiments) in the ratio of 1 to 1.098 in favor of the specimens broken at a temperature of zero. Referring to the frequent breakage of the tyres of railway wheels, he considered that the danger does not arise so much from sudden changes of temperature, as from the practice of heating the tyres to a dull red heat, and then shrinking them on to the rim of the wheels. The unequal, and in some cases severe, strains to which they are thus subjected, has a direct tendency to break the tyres.

Dr. Toule also contributed a paper on the same subject. He agreed in the main with Sir W. Fairbairn. His experiments had shown that wire, exposed to a temperature of 50 deg., was weaker than when tested at 12 deg. The general conclusion at which the author arrives is, that frost does not make either iron (cast or wrought) or steel, brittle; and that accidents arise from the neglect of the companies to submit wheels, axles, and all other parts of their rolling stock to a practical and sufficient test before using them.

Mr. Peter Spence made a short communication, setting forth that certain experiments he had made led to the conclusion that a reduction of temperature increases the strength of cast iron.

We clip from an "Exchange" the following account of the great steel rail mill of the Bethlehem Iron Company, at Bethlehem, Pa.:

The new steel rail mill at Bethlehem, Pa., now erecting by the Bethlehem Manufacturing Company, under the direction of John Fritz, their chief engineer and superintendent, will be, when done, the largest in this country, and one of the largest in existence. It consists of a building 105 ft. wide, spanned by an iron and slate roof without supporters. It is 30 ft. high to the eaves, and is in the shape of a cross, of which the long arm will be 900 ft., and the short arms 142 ft. each, making 1,184 by 105 ft. area, or nearly 3 acres covered. This is only surpassed by the mill at Creusot, in France, which consists of 3 buildings 60 by 1,400 ft. each.

The capacity of the works is to make 300 tons of steel ingots per day, but at present machinery will be erected for rolling but 100 tons of rails, or more than double the capacity of the largest mill yet erected. There will be 8 5-ton converters and 2 train rolls, one of 24 in. and 1 of 28 in. diameter, driven by 2 condensing engines of 48 and 56 in. diameter of cylinders, and 44 and 48 in. stroke.

This mill will be remarkable, not only for its enormous size and capacity, but for the many new labor-saving conveniences introduced into the design of the plant by the engineer. Mr. Fritz, who has examined personally all the Bessemer steel works both here and abroad before designing this.

It is the opinion of experts who have seen it that it will turn out more tons of steel rail, with less manual labor, than any other mill has ever done.

Cleveland Iron Works.—The following is the statement of iron manufacture in 1870, in the city of Cleveland.

| | TONS. |
|---|---|
| Pig iron | 18,575 |
| Rails, iron | 39,367 |
| Rails, steel | 33,000 |
| Rails, steel capped | 3,056 |
| Merchant iron | 17,956 |
| Boiler, tank and sheet iron | 4,250 |
| Forgings | 5,775 |
| Nuts, washers, bolts, nails, spikes | 10,751 |
| Machinery castings | 27,900 |
| Wire, iron and steel | 2,160 |

The consumption during the year of pig and scrap iron was 125,800 tons, and of coal and coke, 372,500 tons. No new mills have been started, but most of those in existence have been extending their capacity.—*Marquette Mining Journal.*

William F. Roberts, Esq., State Geologist of Arkansas, claims for that State great advantages as an iron producer. He states in a letter to the Philadelphia "Press," that 17 years ago, under the auspices of a number of gentlemen living in Philadelphia and New York, he made a hasty examination of the mountainous regions of the State, and obtained satisfactory evidence of the wonderful mineral resources of the State. The money crisis of 1857, and the war following, prevented the execution of laid-out plans to develop them. In regard to coal, he states that although not generally known, there is an immense field in Arkansas.

"Although the limits are at present undefined, yet there are sufficient evidence from the *bared* outcroppings of the coal strata in various places, to show that the field is very extensive. The river Arkansas runs lengthways through this coal formation for more than 150 miles within the limits of the State, and it extends far westward into the Indian nation, and there are many places in Arkansas where the veins might be opened and economically worked above water-level. The advantages in this respect should enlist the attention of coal-mining capitalists of Eastern States to invest some of their surplus earnings in the purchase of coal lands in Arkansas.

"The light, free-burning anthracite found to exist, though in thin strata, in the eastern part of

the Arkansas field, gradually changes into a fat bituminous coal in the western part, where veins are exposed from 5 to 6 ft. thick. At Spadra, on the Arkansas river, 150 miles above Little Rock—river navigation—the coal is similar in structure and appearance to the Cumberland coal of Maryland, and its quality, by analysis, is similar to that famous article of fuel. It is true semi-bituminous—an excellent steam and manufacturing coal. In the upper or western part of the field is a good gas coal, and the bituminous, in some places in this part of the region, approaches the variety called cannel. The anthracite obtained was equally pure in quality, and of as bright, clear fracture as that of Pennsylvania, but this was got from the 'outcrop' of a small seam; larger and workable strata may yet be discovered, when more attention than has been heretofore is directed to the development of this as well as other valuable minerals, which hitherto have been neglected in this State. Cotton, not coal, has been the great attractive staple of Arkansas. In case a pure white ash anthracite does not exist to any great extent as a workable coal, it is certain that semi-anthracite and semi-bituminous do, and that any amount of this kind of fuel can be mined at cheap rates for supplying blast furnaces, rolling mills, and manufactories, to an almost unlimited extent, and for any reasonable time.

"The great coming staple of Arkansas industry, next to coal-mining, will be working the immense deposits of iron ore, which is in great abundance in many places. This State can, without exaggeration, boast of her iron-ore deposits, especially when we take into consideration the various kinds of ore, their generally rich quality, and enormous quantity. This fact is more generally known because it is seen on the surface in mass on the travelled roadsides. Her coal wealth is hid from view, and therefore not appreciated as it should be. Here are the magnetic, hematite, specular, spathic, calcareous, argillaceous, and other varieties of iron ore. Some of the magnetic deposits consist of perfect 'loadstones,' with strong attracting and repelling power, free from any deleterious foreign mixture, equal to the best known elsewhere, for manufacturing steel, and in quantity apparently inexhaustible. The 'limonete' beds in some places cover acres of surface, and where there is great abundance of the best kinds of timber for making charcoal, also limestone of the best quality for fluxing purposes. Never failing, large water-powers are contiguous to the iron ore deposits, and constant river navigation thence to the Mississippi. No State in the Union presents greater facilities for manufacturing charcoal iron economically than Arkansas, and there is a home market for a very large product."

## RAILWAY NOTES.

THE NEW OHIO AND MISSISSIPPI.—We welcome this great line to the family of the standard gauges of our country. At an early afternoon hour of Sunday, Superintendent Griswold announced to the party accompanying him over the narrow gauge as it progressed:

"Gentlemen, I am happy to inform you that the Ohio and Mississippi Railroad is now a narrow-gauge road."

In 8 brief hours the long proposed and well-considered "new departure" had been made a fixed fact.

The Ohio and Mississippi road was completed in 1855. Sixteen years measures more than half in time, and practically the whole in progress, of our railway history. In it date all the improvements—in track, equipment, operation, and policies of transportation—which have raised the locomotive and the rail from a mere rude device of genius, to a perfect instrument, the fruit of accurate study, practical experience, and practised skill. In those early days of yesterday, whatever doubt there may have been in regard to the proper width of track inclined to the side of the now obsolescent broad gauge becoming by hastening steps a thing of the past. At any rate, 4 ft. 8 in. was not thought of as the "gauge of the future." It is since that date that the entire railway system of the South has been built up on a 5 ft. gauge. That, too, will have sooner or later to yield to the stern necessity of "the inevitable." It has now been for many years apparent that the 4 ft. 8 in. gauge would prevail; and the wonder is, in view of the exacting conditions of close connections and through transportation which have of late years obtained, that even so splendid a system as that composed of the Erie, Atlantic and Great Western, and Ohio and Mississippi Railways, should have maintained itself.

It may be suggested that the necessity of the change, for some time recognized by the managers of the Ohio and Mississippi road, possesses a significance as respects what is the true sea-board objective of St. Louis commerce; it is not New York, but Baltimore. Brief time will show. Baltimore people are prone to regard St. Louis as the true interior *entrepot* of the Western trade of their now ambitious and enterprising city. How far this is an opinion, warranted by a consideration of hard facts of topography and trade, and how far a sentiment born of the fellow-feeling of a recent but now forever past industrial and social system,—we shall not undertake to say. At all events, Baltimore now has what New York has long had—a continuous standard-gauge line of railway to St. Louis. The Baltimore and Ohio portion of this route is among the well-built, well-equipped, and well-managed great roads of the country. This latter Company, long content with the rich fruits of her consummate local policies, has very recently become convinced of the value of Western business, and the necessity of at once commanding it. Hence the control secured of the Marietta and Cincinnati road, which has during the past year, been re-created in the image of its master-spirit. Connection thus secured with Cincinnati, the very advantages for which it was secured could not be long sacrificed by the change of gauge, breaking of bulk, and transfer of passengers at that point. The struggle between the broad gauge and standard gauge interests—in a sense between New York and Baltimore,—for the control of the Ohio and Mississippi line would, doubtless, were its secret history known, form a striking chapter in the history of railway diplomacy and war.

With the progress already made in bringing the Marietta and Cincinnati to first-rate condition, and the excellence of permanent way which the Ohio and Mississippi can very soon attain, it will now be due to something besides equal facilities with other cities for travel and traffic west, if Baltimore does not hereafter keep neck and neck with

her competitors in the Western race. The St. Louis "Times" well notes, in its excellent description of the changing of the gauge, that it gives the Ohio and Mississippi 15 m. of additional bed, securing a track foundation not surpassed in this country by virtue of improvements constantly making during 15 years.

The details of the work of changing the gauge have been very fully laid before most readers in the daily press, and we shall only summarize them. Both rails were moved,—a manifest advantage to the road, over the usual process of moving one the entire 15½ in. The inside spikes for the new track had been driven and the ties prepared for the rails; and the gauge had already been changed wherever, as on the sidings, it could be done without embarrassing traffic. Surveys had also been made of the entire line, and a table made of all the curves. For the purposes of the work of moving the rails, to each 5 mile section were allotted 40 men under a Superintendent, and foremen in charge of squads of a half-dozen men. One squad drew the inner spikes of both rails, another moved the rails up to the spikes already driven, and 20 or 30 men followed driving the outer spikes. The number of men immediately engaged was about 3,500, and the "job" was completed in 8 hours.

Up to Saturday night (inclusive) all trains ran through, the traffic of the road not being interfered with. It was no simple matter to keep all the broad-gauge trains, through and local, thus running regularly up to the very act of moving the rail, and at the same time to have the narrow-gauge stock all distributed so as to start trains at once, the moment the "new departure" was taken. Twelve o'clock Saturday night found all the old rolling stock laid up at 6 stations along the line of 340 miles; construction trains were, meanwhile, distributing 10 men to the mile, along the line; and daylight of Sunday saw every engine and car motionless, and the entire main track clear thereof for the only time in 16 years. The silence was, to railroad men, accustomed only to the movement or cars night and day, week day and Sunday,—like the darkness of Egypt—a silence that could be felt. One falls, in speaking of the whole affair, into the language of the battle field. The plans for action all perfectly laid, every company and squad in its place—the men lay for a few silent hours "on their arms" waiting for the dawn. At break of day, some of them at 3.30 A. M., all were "up and at it." By 9.20 the change had progressed sufficiently on the west end of the Road (6¾ miles across the "American Bottom" being finished in 4 hours) that General Superintendent Griswold, accompanied by the other working officers of the road, left with an engine and car to go over the new road.

For several months the machine shops of the road have been working to their full capacity altering rolling stock. The 3 roads now forming the through Baltimore and St. Louis line place 1,000 new cars on the route. The expenditures of the Ohio and Mississippi Railroad Company in the making of the change, including the preparation of the rolling-stock, will amount to $1,500,000. —*Chicago Railway Review.*

THE EUPHRATES VALLEY RAILWAY SCHEME.—We have heard but little lately concerning the once absorbing topic of direct railway connection with India. No doubt the gradual perfecting and completion of the Suez Canal has had a great deal to do with this silence, by attracting the attention of the public from the more direct though inchoate scheme, to that actually put into practice. But the subject is renewed, and now we have the old proposal to construct a railway along the Euphrates Valley again brought prominently into view. In the House of Commons on Friday night Sir Geo. Jenkinson moved for a Select Committee to inquire into the whole subject of railway communication between the Mediterranean and the Persian Gulf, and the House ultimately decided by a large majority in favor of the Committee.

The suggestion to utilize the Valley of the Euphrates is not by any means new, nor is this the first time that motions have been made in connection with it in Parliament. We understand that as far back as the last century the Marquis of Wellesley endeavored to utilize the identical route; and at later dates the House has been asked to grant sums of money for various purposes in connection with it. In most, if not all these cases, money was an object, and was usually directly applied for; but in the present instance all that the mover asked for was an official inquiry which should end in placing upon record all the valuable information now available, including the evidence of Major-General Chesney and others. So far the object is perfectly legitimate and most desirable.

It is not supposed by the promoters of a railway to India that such railway would be in any way antagonistic to the Suez Canal, which would, in all probability, monopolize the heavy traffic, and still exist as the chief means of communication with Southern India. But, on the other hand, the Euphrates line would benefit the north-west provinces, and, as far as passengers and mails are concerned, would effect a saving in time of at least a fortnight, taking the voyage out and home. The saving in distance would be about 1,000 miles in a straight line, and, as vessels proceeding by way of the Red Sea are compelled to deviate from their courses to the extent of 500 or 600 miles during the monsoon months, the saving that might accrue, taking an average of voyages, would be somewhere about 1,000 miles each voyage. Then, on the other hand, the railway would always suffer, from the fact that two transshipments would have to be effected in every case, and this where the goods are bulky is a serious consideration. We have little doubt that any one having to send goods to India—say to Kurrachee—would prefer to send by way of the canal rather than by the railway, though he would save much in point of time by the latter, simply because of the necessary evil we have just pointed out. As a case in point, it was shown that prior to the opening of the Suez Canal goods only of small bulk were sent to India by way of the Isthmus Railway, although the voyage by the Cape occupied 80 days.

Besides the Euphrates Valley, two other routes are also pushed forward as deserving of examination. One of these consists in substituting the Black Sea for the Mediterranean, and making the terminus of the line at Trebizonde. By the champions of this scheme it is contended that the long and dangerous voyage necessitated by a Mediterranean terminus would be avoided by making use of the Danube and the short passage across the Black Sea. Here we have some serious objections to face. On the European side there is the liability of having the Danube, or indeed the Black Sea,

closed, the effect of which would be that the railway would be simply useless, as long as the restrictions remained in force; and on the Asiatic side there would be enormous practical obstacles in the shape of mountain ranges near Trebizonde. The second route is the Tigris Valley. It has been stated that along the Euphrates Valley there would be but little local trade, because after leaving Aleppo the railway would, for 700 miles, pass through a country sparsely populated, whereas by the Tigris Valley route it would open out a better country, and one peopled by more peaceable tribes. Of the respective advantages of the two routes in respect of facilities of construction, we are enabled to state from actual survey that the Valley of the Euphrates is perfectly flat, and that nothing better could be desired in the matter of level, while it is not easy to say what difficulties the Tigris Valley may or may not present. Mr. Eastwick has visited various parts of the Euphrates route, and he states that the facilities there for making a good road are great, and that in certain districts the local traffic would, in all probability, be very considerable. We have for the present simply confined ourselves to a statement of the three systems as they have been laid before Parliament. In our next article we shall have some something to say concerning the engineering points of interest in connection with them.—*The Engineer.*

THE CAR SHOPS OF THE HOUSATONIC RAILROAD — This Company, understanding the advantage of using cars built and repaired by themselves, have always maintained shops for this purpose at their southern terminus, in Bridgeport.

With a force of 14 carpenters, and the proper proportion of other mechanics, Mr. J. Ferris, the Master Car Builder, turns out about 75 cars a year, constructing every part in the shops of the Company.

In the construction of the floor framing, he bolts the bolsters to the under side of the longitudinal floor timbers, and thus avoids cutting into and weakening them.

The side-bearings are fixed at about half the usual distance from the centre bearing, under one of the intermediate longitudinal floor-timbers, thus allowing the truck to swivel more easily, and allowing of smoother motion of the car.

The Company has now 45 milk cars, which may be used indifferently for the transportation of milk or for ordinary freighting purposes. They are the usual box cars, but having, at the front and back ends, ventilating holes 3 in. in diameter, and about 6 ft. above the floor. Two ice-vats, each about 8 in. deep and 2 ft. wide, are provided, fixed about 4 ft. from the floor, extending quite across the car—one at each end. These vats are lined with zinc, and have a waste-pipe for conducting off the water from the ice. The air, entering at the ventilators, passes over the ice in the vats and then finds its way over the floor where the milk cans stand, thus effectually cooling them.

The Company is applying spring-cushioned backs (about 3 ft. 6 in. high) to the seats on one of their passenger cars. Two links are contrived, each hinged at one end to the back, at the other to the arm of the seat, so that the cushion may be turned in the ordinary space, a result which could not be effected in the common way, where there is only one link.

Mr. Ferris make use of a vulcanite emery-wheel for fitting his boxes. This wheel is a cylinder, a little longer than the box and a little less in diameter than the journal, and does its work quite rapidly and without perceptible wear. The boxes, while being ground, are occasionally tested on a mandrel to insure accuracy. Fitted in this way they seldom heat, whereas when they are finished with a file there is considerable trouble on this account.—*The Railroad Gazette.*

ILLINOIS CENTRAL RAILWAY LOCOMOTIVE REPORT FOR MARCH.

| 1871. | Chicago Division. | South Division. | North Division. | Iowa Division. | Total. |
|---|---|---|---|---|---|
| Miles of road | 252¼ | 230¾ | 225 | 401 | 1109¼ |
| MILES RUN: | | | | | |
| By passenger trains | 80,088 | 30,785 | 28,408 | 18,059 | 115,340 |
| By freight trains | 84,753 | 46,417 | 68,059 | 52,801 | 247,030 |
| By other trains | 20,814 | 12,397 | 3,787 | 15,871 | 52,869 |
| Total miles run | 143,655 | 89,599 | 95,254 | 86,731 | 415,239 |
| COST PER MILE RUN: | | | | | |
| Oil, waste and tallow | .66 | .71 | .73 | .54 | .66 |
| Wages | 5.88 | 5.81 | 6.29 | 5.84 | 5 95 |
| Repairs | 9.75 | 7 74 | 11.95 | 7.45 | 9.34 |
| Fuel | 6 00 | 5.63 | 6 80 | 7.21 | 6.36 |
| Cleaning | 1.28 | 1.00 | .99 | .94 | 1.08 |
| Total in cents | 23.58 | 20.87 | 26.76 | 22.00 | 23.41 |
| AVERAGE MILES RUN: | | | | | |
| To one pint of oil | 13.54 | 12.84 | 11 72 | 18.71 | 13 64 |
| To one ton of coal | 37 64 | 38.25 | 31 84 | 39.13 | 35.92 |
| Average number of passenger cars hauled per mile | 5.09 | 4.53 | 4.66 | 3 52 | 4.45 |
| Average freight do. do. | 17.33 | 15.53 | 14.29 | 9 82 | 14.17 |

The above oil includes that used in head lights and in lamps of engineers. Wood is rated at $4.75 per cord; coal, $2.00 per ton on Illinois Central proper; on Iowa Division, wood $5.25 per cord; coal, $2.70 per ton, loaded on tenders; oil, 50 c. per gallon; waste 15c. per pound. Rebuilding, superintending, teaming, and all other expenditures appertaining to repairs, are included in the

above cost of performance of locomotives. Two empty cars rated as one loaded. Whole number of locomotives owned by the Company, 188.

| | |
|---|---|
| Average cost per mile of passenger engines, in cents | 17.86 |
| Average cost per mile of freight engines, in cents | 25 16 |
| Average cost per mile of construction engines, in cents | 14.42 |
| Average cost per mile of switching engines, in cents | 18.74 |

—*American Railway Times.*

CAR COUPLING.—Mr. John A. Mason, of Keokuk, Iowa, is taking measures to introduce a car-coupling of his invention, which, in general appearance, is somewhat similar to the Miller platform. There are compression buffers at the ends of the sills, immediately over the coupling hooks, and the coupling is effected by hooks which spring sidewise, as in Mr. Miller's arrangement. The springs, however, for keeping the hooks together and preserving the coupling, are not attached to the draw-bar, but are spiral springs placed on a vertical shaft, with a hand wheel, and from the shaft is an arm and link connecting with the hook.

The hook differs in form materially from Miller's, and no adequate idea of it can be given without a model or drawing. The inventor claims advantages for it, that automatic coupling may be effected though the cars vary 8 or 10 in. in height; that a much larger bearing surface is secured, and consequently a more reliable connection; that on curves there is no danger of uncoupling; that there is no transverse strain, or shearing stress, of the drawbar—and consequently it may be made much lighter—and that it is applicable to freight cars, and as much "slack" as necessary can be secured.—*Railroad Gazette.*

THE NEW YORK RAILROADS.—The Albany "Argus" prints some interesting figures from the report of the State Engineer of Railroads:

The number of roads operated by steam is 164.

The amount of capital stock paid in is $234,225,159.

The total cost of the construction and equipment of steam railroads is $249,228,896.

The length in miles of the steam roads in the State is 7,166. Length of roads laid 4,773.

Number of first-class passenger cars, 1,229; of freight cars, 34,051.

Number of passengers carried in cars run by steam, 24,550,753. Number of miles travelled by passengers or number of passengers carried 1 mile, 912,626,984.

Total amount of freight, or number of tons carried 1 mile, 2,654,146,549.

The number of passengers carried in city cars during the year was 154,591,871.

The total earnings of roads operated by steam amount to $69,549,444.

A great deal is said about railroad accidents, and the dangers attending travel on railroad cars. The results of 1870 show that 15 passengers were killed by accidents. The average number of miles travelled for each passenger killed was 669,841,798.

According to this showing, the safest place for a person to live would be on a railroad train. The figures are correct, and yet a person might be killed during the first mile of his ride.

An examination of the figures given in the synopsis referred to will disclose other information equally interesting.

## ENGINEERING STRUCTURES.

ILLINOIS & MICHIGAN CANAL—DEEPENING COMPLETED.—The deepening of the Illinois and Michigan Canal, whereby the waters of the lake take their tortuous course up the sluggish channel of the Chicago and into the Illinois river and so gulf-ward—the Chicago river virtually flowing up stream—has, as our readers are well aware, been finally and successfully completed. Our City Fathers, rightly estimating the value and importance of the event, determined upon its commemoration in a style worthy of it and of the city. Accordingly on Tuesday last 4 large canal boats, double decked, or roofed, for the accommodation of the immense crowd of guests invited to join in the festivities of the day, left their dock about 10 o'clock A. M., and in tow of powerful tugs steamed up—or down, more properly speaking—the river and into and down the canal as far as Lemont. The intention was to proceed to Lockport, where the citizens had made ready to welcome the visiting party in a most generous manner. But the unexpected loads, and the slow time necessarily resulting, determined the committee of arrangements to stop at Lemont.

At this point several prominent gentlemen well known as intimately connected with the canal-enterprise, made well received, although off-hand and impromptu addresses, and a very neat and appropriate poem was read.

Hon. C. C. P. Holden, President of our Common Council, having been constituted Chairman of the meeting, presided with his accustomed ease and dignity, and introduced the speakers.

Perhaps we cannot do better, to give an idea of the nature of the enterprise and the difficulties encountered in its prosecution, than present the substance of the speech of W. H. Carter, Esq., Treasurer of the Board of Public Works.

The canal was commenced in 1836 by the State, and so prosecuted till 1842. $4,500,000 had been expended when the work was suspended. In 1845 it passed into the hands of trustees, who raised $1,500,000 to complete it. The original plan was modified, and the high level with pumps, feeders, and locks substituted for a "deep cut." It was completed in the spring of 1848. In 1855 the city had become so large that it became necessary to adopt some system of sewerage; a difficult problem considering the location and low ground. It was finally concluded to adopt the present system, which has worked better than might have been expected; but the great trouble is, they discharge their foul contents into our river until it has become a vile cesspool, endangering health and depreciating the value of property along its margins. Public attention was aroused, and the question how best to cleanse the river was discussed at length. In June, 1868, the Common Council appointed a committee of engineers to examine and report as to the best method of cleansing it. The committee presented 3 plans, but especially recommended the deepening of the "summit" of the canal, which was the course finally entered upon. In September, 1866, the work was contracted and soon after commenced. After about

$200,000 had been expended in 1869, the work was suspended, and contracts abandoned. Then came the tug of war. The whole plan was violently assailed by a portion of the public press; friends of the enterprise began to grow cold; a portion of the Board of Public Works began to waver; the Council began to show signs of timidity. But the friends of the enterprise stood by it firmly. Wise and better counsels prevailed; the order of the Council was again made to proceed, only 2 members voting against it.

In the fall of 1868 the work was finally contracted again, and since then has been energetically prosecuted, especially during 1870, when nearly ½ the entire expenditure has been made.

Finally, on the 15th of this month, a little after 2 o'clock P. M., the coffer-dam that had for a time been holding the waters of the river was cut, and the waters of Lake Michigan took their "new departure."

The speaker paid a just tribute to the Commission—consisting of Messrs. Wm. Gooding and Col. Mason—who were appointed to act with the Board of Public Works in all matters pertaining to the work. Had they failed in 1867, when a portion of the people began to be desponding, and the batteries of the press were turned upon them, he had no doubt the work would have been abandoned. But standing firm and unflinching, they inspired courage, and the work went on.

"'Tis a consummation most devoutly wished for" by our citizens to see the clear, blue water of the lake taking the place of the foul and stagnant pool to which we have been so long accustomed, and for which the less sanguine have prophesied there could be but little or no effective relief. The current down the canal is a strong one, much to the disgust, by the way, of canal boat men, who are now obliged to redouble their tractive force to draw a boat counter to it. What effect the current may have upon the banks of the canal remains to be seen. Many practical men are of opinion that a gate, or lock, or check of some sort will be necessary to control it, especially at high water. But, inasmuch as machinery will probably soon be used on our canals, the other objections to the current will be reduced to a mere nothing.

The entire cost of the work has been $3,116,-281.84; besides for pumping $66,729; discount on bonds $95,682. Tolls lost $43,913. Cubic yards of vertical wall constructed, 1,669; cubic yards of riprap, 24,418; extra work, 30,738 cubic yards.—*Chicago Railroad Review.*

THE GREAT STEEL RAIL MILL IN BETHLEHEM, PA.—The new steel rail mill at Bethlehem, Pa., now erecting by the Bethlehem Manufacturing Company, under the direction of John Fritz, their Chief Engineer and Superintendent, will be, when done, the largest in this country, and one of the largest in existence. It consists of a building 105 ft. wide spanned by an iron and slate roof without supporters. It is 30 ft. high to the eaves, and is in the shape of a cross, of which the long arm will be 900 ft. and the short arms 142 ft. each, making 1.184 by 105 ft. area, or nearly three acres covered. This is only surpassed by the mill at Creusot, in France, which consists of three buildings 60 by 1,400 ft. each.

The capacity of the works is to make 300 tons of steel ingots per day. but at present machinery will be erected for rolling but 100 tons of rails, or more than double the capacity of the largest mill yet erected. There will be eight 5-ton converters and two train rolls, one of 24 in. and one of 28 in. diameter, driven by two condensing engines of 48 and 56 in. diameter of cylinders and 44 and 48 in. stroke.

This mill will be remarkable, not only for its enormous size and capacity, but for the many new labor-saving conveniences introduced into the design of the plant by the Engineer, Mr. Fritz, who has examined personally all the Bessemer steel works both here and abroad before designing this.

It is the opinion of experts who have seen it that it will turn out more tons of steel rails with less manual labor than any other mill has ever done.—*The Railroad Gazette.*

THE INVENTION OF THE STEAM HAMMER.—The evidence of M. Schneider, before the Committee of the Patent Laws on the above invention, has given rise to an animated controversy. From a letter sent to a contemporary by Mr. James Nasmyth, we give the following extract:—"It was on the 23d of November, 1838," writes Mr. Nasmyth, that the first conception of my steam hammer occurred to me, and on account of the simplicity which characterizes this important invention, my first design of it was made out within an hour after; and that with all its distinctive main features, as well as more essential mechanical details, which during the 32 years that have elapsed since, and among the thousands of steam hammers that are the direct offspring of this original design which are doing good service to the world, these distinctive features and mechanical details remain unchanged. M. Schneider speaks of his visiting my works near Manchester, in company with his engineer, M. Burdon (about the year 1840, as I am at present led to believe), and on that occasion discussing with me some notions he then had of a steam hammer, and of comparing them with the designs for my steam hammer, which were on that occasion shown to him. The fact is, I never saw, spoke to, or corresponded with M. Schneider in my life. The visit to my works, to which he refers, was made by him and his engineer while I was absent on a journey, and the designs for my steam hammer were, as an act of civility, shown to him by my financial partner, Mr. Gaskell, who gave him, it would appear, the fullest opportunity to study them, as was often previously done in the case of visits to my works from intelligent strangers. In 1842 I made my first visit to France, having been commissioned by the French Minister of Marine to inspect and report on the mechanical department of the royal dockyards of that country. It was while on that journey, and in entire ignorance at that time that M. Schneider had visited my works, that I called, in passing from the south of France to Paris, at the Creusot Works. M. Schneider happened to be absent, but I was informed that his engineer, M. Burdon, was there. I accordingly introduced myself to him. On observing a fine specimen of forge-work lying in the yard, I remarked the excellence of its execution to M. Burdon, whereupon he, in the most frank and ready manner, said, 'That forging was executed by your steam hammer;' and on asking him how he got to know of my steam hammer, he told me, with equal frankness, the circumstance of his visit to my works during my absence, and of the civility he met with from my partner, Mr. Gaskell, who had laid before

him the designs of my steam hammer, and that on his return to Creusot he had set to work and made one. He then took me to the forge-shop, and there stood my own thumping child before me, with all the distinctive features of the parent indelibly stamped on it."—*Mechanics' Magazine.*

ROCK ISLAND R. (AND WAGON) BRIDGE.—The bridge building by the Baltimore Bridge Co. is an immense affair. There are two spans, 260 ft. each between centres; 3 spans, 221 ft. long between centres; 1 draw, 366 ft. long. The bridge is estimated to carry a load of 5,000 lbs. per ft., for the crossing of teams. The bridge has 2 floors, the bottom one for the crossing of teams. The upper one, for the railway track, is 16 ft. above the former. The iron used in this portion will weigh over 4,000,000 lbs., while the whole structure will weigh over 6,000,000 lbs. It will have 2 sidewalks outside the trusses, each 5½ ft. wide. The trusses are to be 33½ ft. high, and 19½ ft. apart. The draw will be a remarkable feature in this bridge. It will be the heaviest in the world, weighing over 1,360.000 lbs., and will be moved by machinery driven by steam. The bridge, designed by C. Shaler Smith, President of the Baltimore Bridge Company, is to be entirely of iron. Two other spans of 100 and 160 ft. will complete the structure. These will have but one floor, and are intended to serve only as approaches for the railway. Total length of the bridge when completed will be 1,809 ft.

THE CHICAGO RIVER.—Chicago is already jubilant over the flow of its river, and the diminished force of smells which gave the place a reputation second only to that of the ancient city of Cologne. On the 15th of July the last obstacle was removed separating the waters of the Chicago river from a canal destined to carry them to the Illinois river, and a steady but slow current at once set in from Lake Michigan. With the influx of pure water the character of the south branch of the Chicago river at once changed, and though, receiving as it does much of the sewage and refuse of a great city, it is never likely to become a stream noted for its purity, yet a most marked improvement is already manifested. The enterprise of deepening the canal, inaugurated to improve, if possible, the sanitary condition of Chicago, has been a costly experiment, and one that it would have been foolish to attempt without a certainty of good results.

The Legislature of Illinois, in 1865, authorized the city authorities, with the consent of the Canal Trustees, to borrow a sum not exceeding $2,500,000 to be expended upon the work, and enacted that this outlay should constitute a lien upon the revenues of the canal after the payment of its registered debt. At first the scheme was strongly opposed, and work was not commenced until the winter of 1866. The work consisted in deepening the canal between the first two locks, situated respectively at Bridgeport and Lockport, 26 miles apart, from 8 to 10 ft., making the bottom of the canal 6 ft. below low-water mark on Lake Michigan. The canal, west of Lockport, has a declination of $\frac{1}{10}$th of a mile. For the first 16 sections the width of the canal bottom is 44 ft.; from this latter point to section 44 the width is 40 ft. Some idea may be thus formed of the magnitude of the work, the total cost of which, including interest on the bonds, is estimated at over $3,725,000.

Large as has been the sum expended, and great as must be the future expense of the work, there will be no dissatisfaction expressed should it prove successful in purifying the Chicago river. At this writing, though sufficient time has not yet elapsed to fully test the merits of the work, yet the indications are most hopeful. The only doubts which remain are regarding the power of the current formed to keep the river clear, and the possibility that strong winds from the south may at any time drive the water back with a force greater than its flow. Even should this occur, however, which is by no means certain, the condition of the river must be greatly improved by the current acting with favorable winds. It is said that one effect of the work has been to lower the water in the North Branch of the Chicago river, and threaten injury to navigation in that part of the city. It is true that the water has been lowered 2 or 3 in., but there appears no reason why the settling should continue sufficiently to interfere with the passage of boats. The deepening of the canal has had little or no effect in cleansing the North Branch, and some other of the various schemes proposed will doubtless be attempted to secure the end.

The importance of the great work just completed can scarcely be over-estimated. Not only was the condition of the river a standing offence, but a nuisance seriously affecting the health of the city. If the effort to improve the condition of the river prove unsuccessful, there will have been an immense waste of labor and money, and the enterprise will be looked upon only as a blunder; if, on the other hand, it prove even moderately successful, it will be a source of universal gratification, and no tax will be more cheerfully paid than that upon the bonds issued for the work, amounting annually to nearly $330,000.—*The American Builder.*

THE ATCHINSON BRIDGE is a foregone conclusion, soon to be realized. At a meeting at Boston, on the 24th, the representatives of the C. & S. W., C. B. & Q., H. & St. Jo., Central Branch U. P. and A. T. & S. Fe roads agreed to construct a bridge jointly, and arranged to commence work immediately.

## ORDNANCE AND NAVAL NOTES.

HENRY'S DUMMY CARTRIDGE.—The introduction of breech-loading rifles into our service has materially altered the drill, one portion of which is the taking of an imaginary cartridge from an imaginary pouch, and placing it, in imagination, in the chamber of the weapon. The great fault of leaving so much to imagination is, that when the cartridge comes to be actually used, the regular soldier or the volunteer, as the case may be, is awkward at his practice. It is notorious that at the Brighton review a number of cases occurred in which the cartridge became jammed in the breech of the piece. To obviate these accidents, and to familiarize the soldier with the handling of a cartridge, Mr. Henry, the gunmaker, whose barrel has been wedded to the Martini breech-piece, has invented a dummy cartridge, the adoption of which into the service will compass the above objects. It consists of a brass cartridge shell, about ⅛ in. long, with the base attached, and into which is fitted a wooden plug turned down to the size of the bore, and representing the remainder of the cartridge with the conical bullet projecting. The bottom of the dummy car-

tridge is perforated with a ¼ in. hole, into which a plug of india-rubber is fitted. In practising with this cartridge the striker of the gun acts on this buffer plug, and receives no injury whatever, whilst the plug itself is very enduring, one having been used in a rifle some 2,000 times but with little injury. Five or ten of these dummies served out to each man would greatly facilitate his drill, and would prevent clumsiness in practice either with ball or blank cartridge. The dummy cartridge is being introduced by Mr. E. H. Newby, of King William Street, City.

GUNPOWDER.—The Committee on Explosive Substances have just issued a progress report up to the 1st January, 1871. Their experiments have been carried on principally at Woolwich, and the present return gives some interesting details relative to the much-vexed question of gunpowder. Thus with reference to the utilization of our large store of L.G. powder, the Committee remark that there need be no hesitation in interchanging L.G. for R.L.G. on the ground of danger to the gun, although on the whole the latter powder gives somewhat better results. A series of experiments appear to have been carried out in order to determine the battering charges of pebble powder for all the heavy M.L.R. guns, and the results show a considerable increase in the muzzle velocity with all the guns, accompanied by a reduction of maximum pressure as compared with R.L.G. With reference to the effects as regards pressure due to a gun being rifled, the Committee's experiments have effectually disposed of the theoretical dogmas of some philosophers. It has been shown that rifling *per se* has no appreciable effect, provided the projectile or cylinder be of the same weight in both cases. The results appear to indicate that there is no important difference, in either velocity or pressure, between a gun in its rifled and in its smooth-bore state.

GERMAN TORPEDOES.—During the war the strictest secrecy was observed respecting the torpedoes with which the German coasts were protected, but now further information with respect to them has been laid before the public. Electrical torpedoes and those exploding by concussion were both employed. The latter were charged with 75 lbs. of powder, and sunk to a depth of about 3 ft. below the surface of the water. Those exploded from the shore by means of electricity were loaded with 2 centners of dualine, a charge which is equal in force to 10 centners of powder. They were sunk at a depth of about 8 ft. The torpedoes which the "Grille" endeavored to place under the keels of the enemy's vessels were not a new invention, but the old offensive concussion torpedoes, 14 in. in diameter and 2 ft. in length, which did not prove very effective. At Pillou torpedoes charged with 4 centners of powder were improvised. A company for laying and exploding these engines of war was formed at Kiel. In sinking and taking them up 3 accidents occurred, and 14 lives were lost.

SHIPS' LIFE-BOATS.—At the annual general meeting of the Society of Arts, held on the 28th ult., the report was read, which intimated that 44 models and 6 drawings were submitted "in competition for the medal, but inasmuch as one competitor sent in 19 models, the number of competitors was reduced to that extent." After a careful consideration of the models and drawings, the committee, which consisted of Lord H. G. Lennox, M. P., Chairman of Council; Vice-Admiral Sir Edward Belcher; Right Hon. G. J. Goschen, M. P.; Admiral E. Ommanney, C. B.; E. J. Reed, C. B.; Admiral Ryder, etc., were of opinion that none of them sufficiently fulfilled the requirements laid down, or had sufficient merit, either of novelty or otherwise, to justify the award of a medal. The Committee, however, expressed to the Council their disappointment that the models and plans sent in did not sufficiently meet the object which the Society had in view, viz., to get a boat which would do the work at present required by a coaster or ordinary merchant ship, having the additional advantages of a life-boat, with little or no increase of cost. The Committee were of opinion that the subject was too important to be dropped. Accordingly the Council issued a notice for a fresh competition, and 10 communications have been received, which will be submitted to the consideration of the Committee.

## NEW BOOKS.

THE FEDERAL GOVERNMENT, ITS OFFICERS AND THEIR DUTIES. By RANSOM H. GILLETT. New York: Woolworth, Ainsworth & Co.

The author has had a long experience in the courts, besides twenty years of Congressional life.

His book, as he explains in the preface, "is not designed to give minute information to all who hold public office. Its object is to enable the rising generation to understand the structure of our Government, what officers are employed in its practical operation, and their general duties. Such knowledge will be highly useful to all, and especially to the American citizen, when giving direction to public affairs."

The mechanical execution of the book is excellent.

THE ROAD MASTER'S ASSISTANT AND SECTION MASTER'S GUIDE. By WM. S. HUNTINGTON. Chicago: A. M. Kellog. For sale by Van Nostrand.

The author of this little Guide is a railroad builder of many years' experience; a glance at its pages would be sufficient evidence of this, even if we were not assured of the fact from independent sources.

Everything here is regarded from the standpoint of the practical road builder. Under each section the writer sets forth the existing condition of things, whether of material or workmanship, and then follows with concise suggestions for improvement.

The book is divided into 13 chapters, whose titles are:

Track-laying. Laying the rails. About spikes. Cattle-guards. Culverts and turnouts. Ballasting track. Track repairs. Drawing spikes. Repairing switches, etc. Removing ties, snow, and ice. A word to superintendents and road-masters. On fire and water as enemies: also, on preserving fences. On railroad accidents.

As the reputation and life of a railroad depend on the work thus referred to being well done, and as the amount of this work to be done is being enormously increased every year, we trust this little book will be widely read.

THEORY OF GUNNERY. By P. ANSTRUTHER, Maj.-Gen. London: E. & F. N. Spon. For sale by Van Nostrand.

This is a pamphlet containing an exposition of the author's views respecting the methods of computation for range of projectiles. The author especially desires that his views shall be tested by the War Department, and offers the present paper to the Institution of Civil Engineers (English).

POWER IN MOTION. By JAMES ARMOUR, C. E. London: Lockwood & Co. For sale by Van Nostrand.

This is a thoroughly practical treatise, and devoted to the applications of the ordinary principles of mechanics, to the use of wheel gearing, belts, wire rope, and the simple elements of machinery in general.

The rules for belting are well given and fully illustrated. The elucidation of the principles of revolution of force and motion is adapted to the comprehension of those not skilled in the advanced methods of analysis.

THE GAS CONSUMER'S GUIDE: A Book of Instruction on the Proper Management and Economical Use of Gas. With a full description of Gas Meters, and Directions for Ascertaining the Consumption by Meter. On Ventilation, etc., Alexander Moore, Boston; S. C. Griggs & Co., Chicago. For Sale by Van Nostrand.

There is, perhaps, no single item of expense connected with living and working, which is paid with as much unwillingness as are gas bills. The majority of people are unable to tell whether or not the amount claimed from them is justly due, and with a universal lack of faith in human nature, conclude that they are overcharged, and, it must be admitted, that not a few of the gas companies give to their customers grounds for believing in the doctrine of total depravity, at least as regards corporations. People pay too much money for gas, but not always from any fault of the producers. There is an economical and an extravagant way of burning gas, but the knowledge of these ways is confined to the few. It includes an acquaintance with the different kinds of burners and their relative merits, and of the best means of regulating the supply by the meters commonly in use.

To give this needed knowledge is the object of the little book of which the title is given above, and it appears well adapted to the purpose. As an index to the inclusiveness of its contents, it may be stated, that, besides giving a brief history of the means of artificial light, it explains the manner of manufacturing gas, describes the varieties and estimates of the different fittings, brackets, burners, flames, reflectors, etc., and gives at length, what constitutes one of its greatest merits, the means of reading meters and managing gas in the various uses to which it is put. The work concludes with a short treatise on ventilation, which contains many valuable suggestions, and we have no hesitation in commending the book, as one which will amply repay any consumer of gas for its purchase and the trouble of reading.—*American Builder.*

A FEW WORDS ABOUT GASES. By C. C. GRINDY. London: Simpkin, Marshall & Co., 1871.

This little book of 58 pages, which is supplied to working men at 6d. a copy, is written "for those who have little time or money to spend in the acquisition of information not immediately connected with their occupations." A great many important truths are to be learnt in the study of the properties of these powerful agents, which are too often neglected, simply because they are invisible. And not a few of these lessons Mr. Grindy teaches with great clearness and accuracy. The writer well deserves encouragement.

BRIDGES' GUNNER'S POCKET-BOOK. Compiled by CAPTAIN T. W. BRIDGES, H. P. Royal Artillery. London: E. and F. N. Spon, 1871. For sale by Van Nostrand.

Were we in want of an excuse for noticing this little military manual, we might find it in the fact that the Volunteer Artillery Corps are largely recruited from the various branches of the engineering profession. Captain Bridges has compiled this pocket book, which contains various tables, formulæ, abridged gun-drills, ranges, and miscellaneous artillery memoranda, from sundry manuals of a similar kind, but of a larger size; his object being to produce a miniature work which could be carried in a uniform pouch. As a rule, we object to the practice of trusting entirely to a formula-book in the pocket, instead of data and principles clearly arranged in the head. Those who rely too implicitly on such aids are sure to find themselves sooner or later without them in some emergency, and in consequence, as much at a loss as Mr. Bouncer, in "Verdant Green," at his examination, when his reference cards would not work. At the same time artilleymen are expected to remember such an enormous quantity of petty facts, weights, dimensions, ranges, elevations, etc., that in their case there is really some excuse for a memorandum-book like the one before us. But we think that Captain Bridges might have arranged the contents better, and classified them with advantage under the respective heads of Field and Garrison Artillery. As it is, we find the "Weight of Forage," and "Marks on cast-iron Ordnance," in juxtaposition; while the composition of light and smoke balls, and the formulæ for piles of shot and shell, are introduced inio the middle of memorada useful chiefly to troops on the march. Some notes on judging distances and finding ranges in the field would have been a useful addition; the omission of all reference to the Moncrieff gun-carriage is a noticeable defect. In fact, possibly owing to its being the work of an officer on half-pay, the information generally seems scarcely up to the present time. We trust at least that the Artillery carbines, patterns 1853 and 1861, the only ones described, are quite out of date.

THE METALS USED IN CONSTRUCTION: IRON, STEEL, BESSEMER METAL, ETC. By FRANCIS HERBERT JOYNSON. Illustrated. W. P. Nimmo, Edinburgh. For sale by Van Nostrand.

To all engineers and mechanics, to all artists and artisans in metals, this little work on the metals used in construction, the greater part of which is devoted to iron and steel, will be interesting and useful. There can be no question that perfect knowledge of the material wrought is necessary for every worker. In the hand-book before us the chapters are severally entitled: cast-iron, malleable, or wrought-iron, steel, copper, lead, zinc, tin, galvanized iron, brass, alloys, and miscellaneous notes connected with the manipulation of metals. As a book of reference for

youths entering the workshop it is invaluable, and all searchers after knowledge will find in it much that is practically good, and could only be obtained from a man who had gained his experience practically.

TRIUMPHS OF INVENTION AND DISCOVERY IN ART AND SCIENCE. By J. HAMILTON FYFE. With illustrations. London: T. Nelson & Sons, 1871.

This is one of those "Books for Boys," which the publishers have distinguished themselves by bringing out, in form beautiful, yet inexpensive; and in matter, sound and healthy, while attractive. Mr. Fyfe's plan is good, and admirably carried out. In his 13 chapters, descriptive of so many branches of art or industry, the leading incidents in the lives of the chief inventors and discoverers are related, while a clear summary is given of the present condition of each department. The account of the art of Printing relates the feats of Gutenburg and Caxton; and that of the "Steam Engine" the inventions of Lord Worcester and James Watt. "Railways" are associated with a history of the Stephensons; and the "manufacture of cotton," with the improvements made by Kay, Hargreaves, Arkwright, Crompton, Cartwright, and Sir R. Peel. The "Lighthouses" described are those of Eddystone, Bell Rock, and Skerryvore; and the "Iron Manufacture" is traced in the Life of Henry Cort. "The Ocean Steamers" of the present day are traced from the inventions of Symington, Fulton, and Bell; and the chapter on the Electric Telegraph gives a very clear account of the experiments of Cook and Wheatstone. Under "Silk Manufacture" is a narrative of the lives of Tombe, Lee, and Jacquard. And under "Potter's Art," a history of Della Robbia, Palissy, and Wedgwood. Three other chapters relate to the Miner's Lamp and Davy's Life; to the Postal System, and Sir Rowland Hill; and to the Overland Route, from the adventures of Lieutenant Waghorn to the final success of the Suez Canal. This book has very substantial merits. It does not deal in the merely romantic incidents of invention, but clearly and accurately presents the leading facts in the history of each department in a manner which becomes doubly interesting and instructive, for our ingenious youth, by being interwoven with the life-history of many noble mechanics of olden times.

## MISCELLANEOUS.

THE American Institute of Mining Engineers completed its organization at its first regular meeting on 16th, 17th, and 18th of May.

The names of its officers and enrolled members afford promise of a high degree of usefulness for the future.

The officers are as follows:

*President*, David Thomas, Catasaqua, Pa.

*Vice-Presidents*, R. W. Raymond, New York, N. Y.; E. B. Coxe, Drifton, Pa.; W. R. Symons, Pottsville, Pa.; W. P. Blake, New Haven, Conn.; J. F. Blandy, Philadelphia, Pa.; J. H. Swoyer, Wilkesbarre, Pa.

*Managers*, R. P. Rothwell, Wilkesbarre, Pa.; T. S. McNair, Hazleton, Pa.; G. W. Maynard, Troy, N. Y.; Raphael Pumpelly, Cambridge, Mass.; Thos. Petherick, Scranton, Pa.; T. M. Williams, Wilkesbarre, Pa.; Thomas Eagleston, Jr., New York, N. Y.; E. Gaujot, Pottsville, Pa.; Fred Prime, Jr., Easton, Pa.

*Secretary*, Martin Coryer, Wilkesbarré, Pa.

*Treasurer*, J. Pryor, Williamson, Wilkesbarre, Pa.

THE PRODUCTION OF BRIGHT OR LUSTROUS COLORS ON METALS.—The active chemist, C. Puscher, of Nuremberg, proposes a new method of coloring metals which can be executed quickly and cheaply. He produces on these surfaces a coating of metallic sulphides analogous to those found in nature, as for example, sulphide of lead. These very stable sulphur combinations, as is well known, are not affected by ordinary agents. According to Puscher's method, in 5 minutes there may be imparted to thousands of brass articles a color varying from a beautiful gold to a copper red, then carmine red, then dark, then light aniline blue, to a blue white, like sulphide of lead, and at last a reddish white, according to the length of time they remain in the solution used. The colors possess the most beautiful lustre, and, if the articles to be colored have been previously thoroughly cleansed by means of acids and alkalies, they adhere so firmly that they may be operated upon by the polishing steel. To prepare the solution, dissolve 1½ oz. of hyposulphite of soda in 1 lb. of water, and add 1½ oz. acetate of lead dissolved in ½ lb. of water. When this clear solution is heated to 190 deg. to 210 deg. Fahr., it decomposes slowly and precipitates sulphide of lead in brown flocks. If metal is now present, a part of the sulphide of lead is deposited thereon, and according to the thickness of the deposited sulphide of lead the above-mentioned beautiful lustre colors are produced. To produce an even coloring, the articles to be colored must be evenly heated. Iron treated with this solution takes a steel-blue color; zinc, a brown color; in the case of copper objects, the first gold color does not appear; lead and zinc are entirely indifferent. If instead of the acetate of lead, an equal weight of sulphuric acid is added to the hyposulphite of soda and the process carried on as before, the brass is covered with a very beautiful red, which is followed by a green, which is not in the first-mentioned scale of colors, and changes finally to a splendid brown with green and red iris-glitter; this last is a very durable coating, and may find special attention in manufactures. Very beautiful marblized designs can be produced by using a lead solution thickened with gum-tragacanth on brass which has been heated to 210 deg. Fahr., and is afterward treated by the usual solution sulphide of lead. The solution may be used several times, and is not liable to spontaneous change.—*Technologist.*

THE March number of the "Journal des Savants" contains the first portion of a very interesting article on flying machines (written in the form of a review of Marey's "Flight of Birds"), from the pen of M. J. Bertrand, of the French Institute. He combats the notion of applying the well-known principles of the mechanical theory of heat to the explanation of the flight of a bird, and points out that no trustworthy observers have as yet "taken the precaution of weighing a carrier pigeon at the beginning and end of its journey," and no one has yet answered the question, "What is the number of grammes of carbon representing the combustion accomplished by the respiration of the

bird during its journey?" The author takes the case of the swallow, the weight of which he puts at 15 grammes, and which is capable of maintaining a velocity of 15 metres per second for more than an hour. According to Navier the work developed is then 0.015 (kilo.) × 390 × 3,600 = 21,260 kilogrammetres, or 50 calories, that is to say, about equal to the heat produced by the combustion of 8 grammes of *pure* carbon. It is obvious that the entire body of the bird would be totally insufficient to furnish this amount. Being entirely free from mathematical or geometrical technicalities, the article is a very readable one.

FALLACIES OF SEASONING LUMBER.—A letter from Mr. H. G. Buckley, of Chicago, has been published, boldly attacking the old system of seasoning lumber in the open air or in kilns, as inefficient and contrary to sound reason. He gives a few practical tests to show the great advantages of the use of dry steam, as follows:

I was furnished by the Rogers Locomotive Manufacturing Company, at Paterson, N. J., with a sample of their best air-dried lumber to see if I could shrink it in dry steam. As strange as it may appear, it shrank $\frac{7}{16}$ in. to the foot in 2 days as a part of 30,000 ft. of lumber in the same room. A sample of black walnut timber from the car shops of the Hudson River Railroad shrank $\frac{6}{16}$ in. to the foot in 1 day. Some staves from a pail and tub factory that had been dried both in the air and in a hot air kiln shrank more than an inch to a pail in 1 day; and entirely green staves were equally well shrunk and dried in the same room and in the same length of time. Some gunstocks at the United States Armory, at Springfield, were more thoroughly shrunk in 2½ days in dry steam, than others that had been dried in the air under cover for 8 years. Those sticks that were prepared from the green, in 2½ days could be selected in the dark, from the 8 years air-dried, by their superior finish. Some timber at Pittsburg, known to have been air-dried for more than 60 years, and used for building gun carriages, was tested by baking, with some of the same size that had been prepared from the green in 48 hours in dry steam, and to the surprise of many, the 60 years air-dried wood shrank nearly double that of the steam-dried. Thousands of such cases can be furnished to those who are sceptical, or new tests can be made for their especial benefit. One person who was sceptical dried a piece of lumber 3 years in a yard and 1 whole year in a hot-air kiln, and yet the dry steam shrank it $\frac{3}{16}$ in. to the foot, and diminished its weight.

But the drying of lumber has very little importance in comparison with its being seasoned and shrunk. Six green gun-stocks, as a part of 9,000 in the same inclosure (16 by 20 ft.), at the Springfield Armory, shrank in weight the first day, 12 lbs. 3 oz.; the second day, 5 lbs. 5 oz.; the third day, 2 lbs. 13 oz. The same stocks shrank in size, the first day, $\frac{3}{4}$ in.; the second day, $\frac{1}{64}$ in.; the third day, none; thus showing that the shrinking in size stops before the timber is quite dry. There is, therefore, no advantage in drying timber after the shrinking in size stops, under a seasoning heat of dry steam.

One of the great advantages of seasoning and shrinking of lumber by dry steam is, that the lumber can never afterwards be exposed to a higher degree of heat or a more thoroughly shrinking atmosphere, unless it is actually burned to charcoal. Another advantage is, that a day in dry steam has produced better shrinkage, on an average, than a year in the air. Practical men can readily sum up the interest on capital, storage, checks, splits, warps and decay, and see if that do not amount to more than $1 per 1,000 ft., which is about the average cost of thoroughly seasoning, shrinking, and drying of lumber by dry steam.

THE NAVIGABLE WATERS OF ILLINOIS.—Few have any adequate idea of the extent of the navigable waters in and around Illinois. We estimate that the steamboat routes of the State are ¼ as long as the railroad lines, and these navigable waters have had much to do with the prospects and rapid growth of the State.

There are in and on the boundaries of Illinois the following routes of navigable streams on which steamboats run:

| | MILES. |
|---|---|
| Mississippi River, Cairo to Dunleith | 678 |
| Ohio River, Cairo to mouth of Wabash | 118 |
| Illinois River, mouth to La Salle | 324 |
| Total | 1,120 |

Besides, the Wabash, on the southeast boundary, is navigable for about 180 miles of its crooked course, and there is about 70 miles of the coast of Lake Michigan on our northeast border. There are, or have been, steamboats on the Fox and Rock rivers, though they can hardly be called navigable, and these steamers have run somewhere on their upper courses, above many dams, which cut them off from their mouths. The Kaskaskia, also, we believe, has been navigated by steamboats, and the raging canal bears canal boats from Bridgeport to La Salle, 96 miles. The plans for the improvement of the Kankakee and Illinois rivers, if carried out, will add about 100 miles to the sum given above.

BORNEO COMMERCE.—The demand that sprang up last year for gutta-percha, and which has gone on steadily increasing, has infused a great activity into the whole country, and so long as the present high rates are given, the native dealers and collectors will continue to bring it to market. The difficulty of obtaining it is now much greater than in former years, as, owing to the reckless way in which trees are felled and the gutta-percha extracted, they have almost entirely disappeared from the neighborhood of the rivers, and collectors have now to penetrate much further into the forests in search of the trees than was formerly the case. This is one of the reasons that have caused the price to rise so high in so short a time, but probably the chief reason is the competition which thus has lately arisen. Formerly, one firm was the large purchaser, but now agents for Singapore firms have entered the Sarawak market. The price of gutta-percha, which, in the early part of 1869 was from $25 to $25½ the picul of 133 lbs., has more than doubled, having gradually risen from $65 to $115 the picul. The Cinnabar mines, worked by the Borneo Company, may now be considered fairly started. Retorts have been erected during the past year, and a fair quantity of quicksilver has been obtained. The great difficulty of transport, however, enhances the cost of working very considerably. The antimony mines are yielding good ore, in fair quantities.